U. S. ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, DC 20460

OFFICE OF
PREVENTION, PESTICIDES
AND TOXIC SUBSTANCES

PC Code 079401
DP Barcodes   D238673, D191905, D224730,
D198346, D259123, D259983, D260709, D262998

MEMORANDUM

DATE: April 13, 2001

SUBJECT: EFED Risk Assessment for the Reregistration Eligibility Decision on Endosulfan (Thiodan®)

TO: Stacey Milan, Product Manager
                Michael McDavitt, Acting Branch Chief
                Reregistration Branch
                Special Review and Reregistration Division (7508C)

FROM: Nelson Thurman, Senior Environmental Scientist
                José Luis Meléndez, Chemist
                Dirk Young, Ph.D., Environmental Engineer
                Thomas Steeger, Ph.D., Fishery Biologist
                Rodolfo Pisigan, Ph.D., Environmental Chemist
                Richard Lee, Ph.D., Biologist
                Endosulfan Risk Assessment Team, Environmental Fate and Effects Division (EFED)

THROUGH: Mah T. Shamim, Ph.D., Chief
                Environmental Risk Branch V, Environmental Fate and Effects Division

The EFED environmental risk assessment for endosulfan reregistration for use on both food and non food crops is attached. The risk assessment incorporated nonconservative assumptions in its aquatic risk assessment and includes a probabilistic exposure assessment for aquatic impacts. In addition, because the risk assessment did not take into account the toxicity of the primary transformation product endosulfan sulfate, which is equal in toxicity to the parent endosulfan, the overall terrestrial and aquatic risk of endosulfan is underestimated by the contribution of endosulfan sulfate to the total exposure. The risk assessment has been revised based on comments made by the registrant (Endosulfan Task Force). Based on an earlier request by SRRD, EFED included a comparative risk assessment, which is being conveyed under a separate cover.

Endangered Species

Although the U.S. Fish and Wildlife Service issued a biological opinion on endosulfan in 1989 many additional species have been federally listed since that time and determination of jeopardy to these newly listed species has not been assessed. Additionally, the 1989 biological opinion did not consider endangered insects. Since no data were available to assess the toxicity of endosulfan to terrestrial and aquatic plants, the risk of endosulfan to threatened/endangered plants is unknown.

Data Gaps

EPA received 206 ecological effect studies in support of the reregistration of endosulfan. Although many (78%) of the studies did not comply with current EPA guideline requirements, toxicity endpoints were consistent within species assemblages and provided compelling evidence of the toxicity of technical grade endosulfan (racemic mixture of ˝ and ˘ isomers) and its formulated end products. These studies show that endosulfan is very highly toxic to both terrestrial and aquatic organisms. Although EFED has historically required additional data to verify its concerns regarding the toxicity of chemicals it believes to represent an ecological risk, EFED believes that the toxicity of endosulfan has been clearly established through the existing studies and is now only requesting that technical grade endosulfan be subjected to additional testing of its endocrine-disrupting potential. Since endosulfan binds to the estrogen receptor and has demonstrated reproductive and developmental effects, EFED recommends that, when appropriate screening and/or testing protocols being considered under the Agency's Endocrine Disruptor Screening Program have been developed, endosulfan be subjected to more definitive testing to better characterize effects related to its endocrine disruptor activity. Additionally, although open literature indicates that both isomers (˝ and ˘ -endosulfan) and the endosulfan sulfate degradate are toxic, EFED has no specific toxicity data with which to evaluate the toxicity of endosulfan sulfate. Thus, EFED requests that the following data be provided on the endosulfan sulfate degradate:

1.   Avian acute oral toxicity of bobwhite quail and mallard ducks (Guideline 71-1)
2.   Avian subacute dietary toxicity of bobwhite quail and mallard ducks (Guideline 71-2)
3.   Avian reproduction study (Guideline 71-4)
4.   Freshwater fish acute toxicity study of rainbow trout and bluegill sunfish (Guideline 72-1)
5.   Freshwater invertebrate acute toxicity study of Daphnia magna (Guideline 72-2)
6.   Freshwater fish full life cycle using rainbow trout (Guideline 72-5)
7.   Estuarine/marine fish acute toxicity study (Guideline 72-3)
8.   Estuarine/marine invertebrate acute toxicity study of mysid shrimp (Guideline 72-3)

Additionally, given the likely association of endosulfan with benthic sediments and the toxicity of endosulfan to aquatic organisms, EFED requests that the following data be provided on both technical grade endosulfan and the endosulfan sulfate degrade:

9.   Whole sediment acute toxicity testing using a freshwater invertebrate.
10.   Whole sediment acute toxicity testing using an estuarine/marine invertebrate
11.   Whole sediment chronic toxicity testing using a freshwater invertebrate.
12.   Whole sediment chronic toxicity testing using an estuarine/marine invertebrate.

The risk assessment conclusions are not dependent on the results of these studies and the submission and review of the studies should not provide a reason to delay the re-registration eligibility decision for endosulfan. The data are intended to confirm reports that endosulfan sulfate degradate has toxicity similar to that of the parent. The data will not lessen EFED's current assessment of risk since the toxicity of the degradate was not considered in calculating RQ values but was only alluded to as an uncertainty. If anything, the additional data could increase EFED's concerns regarding the cumulative toxicity of the parent endosulfan and its degradate.

Recommended Label Language

The following precautionary statements should be included on both manufacturing use labels and end sue product labels

Environmental Hazards

Do not apply directly to water, or to areas where surface water is present or to intertidal areas below the mean high water mark. Do not contaminate water when disposing of equipment washwater or rinsate.

Drift and runoff may be hazardous to aquatic organisms in water adjacent to treated areas.

This pesticide is toxic to birds and mammals.

This pesticide is extremely toxic to fish and aquatic invertebrates. Do not apply directly to water, to areas where surface water is present, or to intertidal areas below the mean high water mark. Drift and runoff may be hazardous to aquatic organisms in water adjacent to treated areas. Do not contaminate water when disposing of equipment wash waters or rinsate."

This product is toxic to bees exposed to direct treatment or residues on blooming crops or weeds. Do not apply this product if bees are visiting the treatment area.

Observe all cautions and limitations on labeling of all products used in mixtures.

Surface Water Label Advisories

This product may contaminate water through drift of spray in wind. This product has a potential for runoff according to the pesticides "mean" soil partition coefficient (K_d) for several months or more after application. Poorly draining soils and soils with shallow watertables are more prone to produce runoff that contains this product. A level, well maintained vegetative buffer strip between areas to which this product is applied and surface water features such as ponds, streams, and springs will reduce the potential for contamination of water from rainfall-runoff. Runoff of this product will be reduced by avoiding applications when rainfall is forecasted to occur within 48 hours. Sound erosion control practices will reduce this product's contribution to surface water contamination.

In addition, EFED notes that the detection of the pesticide in ground water typically triggers a **Ground Water Advisory**. The assessment did not emphasize endosulfan occurrence in ground water and endosulfan does not exhibit the characteristics normally associated with those pesticides that are frequently detected in ground water. However, endosulfan has been detected in some wells and, in the water resource assessment, EFED attempted to describe the conditions under which such movement to ground water are likely to occur.
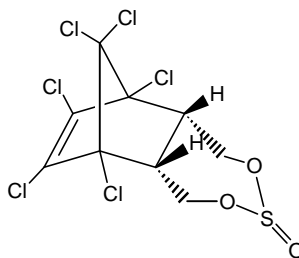
Environmental Fate and Ecological Risk Assessment
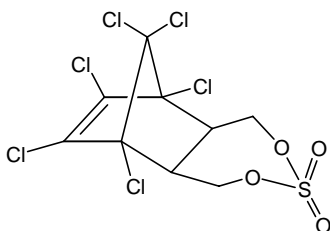## for the Reregistration Eligibility Decision
on Endosulfan
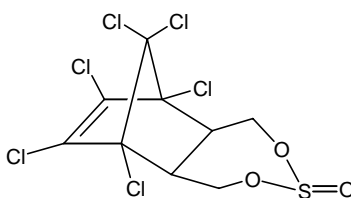
endosulfan

(115-29-7)

(stereochemistry unspecified)
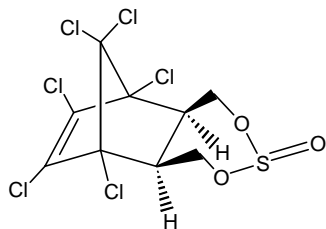
alpha-endosulfan

(959-98-8)

beta-endosulfan

(33213-65-9)

endosulfan sulfate

(1031-07-8)

Executive Summary

A screening assessment for terrestrial impacts and a non-conservative refined assessment for aquatic impacts indicate that endosulfan is likely to result in acute and chronic risk to both terrestrial and aquatic organisms. This assessment is supported by monitoring data showing widespread contamination of surface water and incident data showing that endosulfan's current use represents a serious risk of non target mortality for aquatic species. OPP conducted a more refined aquatic risk assessment using probabilistic exposure assessment techniques based on actual reported application rates in California coupled with a 300-ft spray drift buffer. This refined assessment projects that on sites prone to runoff within the endosulfan use area, mortality to nontarget fish is probable in any given year. This ranges from a 10% probability that 10% of all non target aquatic species in a population will suffer 50% mortality for the least vulnerable crop (apples) to a 90% probability that roughly 60% of all the aquatic species will suffer 50% mortality for the most vulnerable uses (tomatoes). Although the 300-foot buffer may provide additional benefits in reducing runoff loads into surface water, it is not specifically designed to reduce runoff and runoff studies conducted by the registrants showed mixed results. The assessment conclusions are supported by incident data which shows that multiple fish kill incidents attributable to endosulfan use are reported each year. While repopulation is likely through downstream migration from unaffected areas, the intermediate effect on food chains is uncertain.

Although the screening level and refined risk assessments make assumptions about exposure and effects, the assumptions for this assessment are not particularly conservative. This assessment focused primarily on aquatic risk; however, endosulfan is clearly a risk to terrestrial non target organisms as well. While the refined risk assessment addresses the probability and magnitude of acute effects, the risk of chronic effects is also significant, given chronic risk quotients several orders of magnitude greater than acute values, endosulfan's capacity to act as an endocrine disruptor, and the persistence of both the parent and its toxic transformation products. The likelihood of ecological effects is based on surrogate species considered representative of species found in areas where endosulfan is used. The sensitivity of the surrogate species may not however, be representative of the most vulnerable organisms. While the refined assessment attempted to account for a range of sensitivities, it remains uncertain whether the full distribution of effects has been captured.

The aquatic risk characterization is based on both the current maximum application rates and intervals and more "typical" rates and intervals for major crops on which endosulfan is used. Even at typical application rates, endosulfan is likely to result in acute and chronic risk to aquatic species. While atmospheric transport has been documented for endosulfan, insufficient data exist to account for its potential contribution to ecological exposure. Outside of incidents associated with organophosphate pesticides and carbofuran, endosulfan-related incidents account for the greatest percentage of non target mortality reported in EPA's Ecological Incident Information System and confirm EFED's expectation that endosulfan's current use represents a serious risk of non target mortality. EFED has projected that even using nonconservative assumptions (i.e., "typical" application rates and a 300-foot spray drift buffer), current endosulfan use rates on 88% of the crops modeled will exceed acute high risk LOCs more than 99% of the time. Although incident reports confirm the likely acute effects that EFED expects based on exceedances for acute LOCs, chronic RQ values ranging as high as 487 also make it likely that endosulfan will result in possibly chronic effects. Given the reproductive and developmental effects of endosulfan coupled with the chemical's ability to bind to the human estrogen receptor, these chronic effects could have a considerable impact on non target organisms, including humans.

INTRODUCTION

Endosulfan is a dioxathiepin (broadly classified as a chlorinated hydrocarbon) insecticide and acaricide. Technical endosulfan is made up of a mixture of two molecular forms (stereo isomers) of endosulfan – the alpha (˝) and beta (˘) isomers. This arylheterocycle acts as a poison to a wide variety of insects and mites on contact through blockage of GABA- (gamma amino butyric acid) gated chloride channels. Dissociation studies (Rauh *et al.* 1997) showed that dieldrin, ketoendrin, toxaphene, heptachlor epoxide and ˝- and ˘-endosulfan competitively bind with GABA receptors.

 Stimulation of the central nervous system is the major characteristic of endosulfan poisoning (Ecobichon 1991). Additionally, animal data indicate that toxicity may also be influenced by species and by level of protein in the diet; rats which have been deprived of protein are nearly twice as susceptible to the toxic effects of endosulfan. Solvent and/or emulsifiers used with endosulfan in formulated products may influence its absorption into the system via all routes: technical endosulfan is slowly and incompletely absorbed into the body whereas absorption is more rapid in the presence of alcohols, oils, and emulsifiers (Gupta and Gupta 1979).

This broadly labeled pesticide is used on a wide variety of row crops, fruits, nuts, vegetables, cotton, and specialty and minor-use crops. Endosulfan may be formulated as a single active ingredient or combined with methyl parathion, packaged as an emulsifiable concentrate or a wettable powder. It is not compatible with alkaline materials because it is susceptible to hydrolysis at alkaline pH values.

General Use Information

Data provided by OPP's BEAD and by the registrants (Endosulfan Task Force) show that the total amount of endosulfan applied in recent years ranged from approximately 1 million to 3.3 million pounds of active ingredient per year (reported from several sources for the years between 1994 and 1997). Endosulfan is used on a wide variety of crops, with major usage on apples and pears, cotton, potatoes, tomatoes, tobacco, cucurbits, pecans, stone fruit trees, lettuce, and grapes. Typical application methods are aerial spray, ground spray and ground blast. Major use areas cover extensive portions of the United States, especially Arizona and California, the Pacific Northwest, Texas, the Southeast, Maine, and the northern tier of states ranging from Delaware and New York west to Indiana and Michigan.

The Water Resource Assessment contains a discussion of the uses considered in this risk assessment. The refined risk assessment section includes additional information on the ranges of "typical" application rates for the crops used in this risk assessment. More detailed usage information can be found in BEAD's usage evaluation in the RED document.

ENVIRONMENTAL FATE ASSESSMENT

Overview

Based on the environmental fate properties of each isomer (˝- and ˘-endosulfan), technical grade endosulfan is a mixture of two biologically-active isomers which differ in physico-chemical and fate properties. Endosulfan is a persistent, semivolatile compound that has been detected in nearly all

environmental compartments, including water and in areas where it is not used (e.g., the Arctic and national parks). The end-use product is a mixture of two endosulfan isomers, typically 70% α-endosulfan and 30% β-endosulfan. The β-isomer is generally more persistent and the α-isomer is more volatile. For both isomers, hydrolysis at pH values greater than 7 is an important degradation route; however, at pH values below 7, both isomers are rather persistent. At a pH of 7, α-endosulfan and β-endosulfan hydrolyze with half-lives of 11 and 19 days, respectively, and at a pH of 9, the isomers have half-lives of 4 to 6 hours. Some open literature studies indicate that the hydrolysis half-life may be somewhat longer (but of the same order of magnitude) at pH 7. Under acidic conditions, both isomers are stable to hydrolysis, and microbial degradation in soils becomes the predominant route of degradation. Half-lives in acidic to neutral soils range from one to two months for α-endosulfan and from three to nine months for β-endosulfan under aerobic conditions. Dissipation rates observed in field studies, which capture a combination of degradation, transport, and uptake, suggest that endosulfan will persist in the surface soil for weeks to months after application. Field dissipation rates were similar to those reported in laboratory soil metabolism studies.

The major transformation products found in the fate studies are endosulfan diol (hydrolysis) and endosulfan sulfate (soil metabolism). Both the diol and sulfate transformation products have backbone structures similar to the parent compound (Figure 1) and are also of toxicological concern. Available data suggest that endosulfan sulfate will be more persistent than the parent. The estimated half-lives for the combined toxic residues (endosulfan plus endosulfan sulfate) ranged from roughly 9 months to 6 years.

Laboratory studies indicate that α- and β-endosulfan have a high affinity for sorption onto soil and are not expected to be highly mobile in the soil environment. However, because of endosulfan's resistance to degradation, it can persist long enough to be transported to both ground- and surface-waters, as monitoring studies have shown. Endosulfan can contaminate surface waters through spray drift and transport in runoff. In addition, endosulfan may move to targets beyond its use area through atmospheric transport (via volatilization, transport on dust particles, or a combination). Within the water bodies, endosulfan tends to be sorbed onto sediment and plants.

Table 1 summarizes the environmental fate characteristics of endosulfan. Appendix A provides a more detailed discussion of the studies used in this assessment; Appendix B summarizes published scientific studies used to supplement the fate assessment of endosulfan. This assessment relies primarily on the studies provided by the registrants while using the published literature to fill in gaps or highlight areas of concern that are not identified by the core studies. The cited literature drawn only from scientifically peer-reviewed publications are only considered as supplemental information and are not intended to fulfill any outstanding guideline requirements.

Table 1: Summary of Environmental Chemistry and Fate Properties of Endosulfan (See Text for Discussion)

Parameter	Value	Reference/Comments *
Selected Physical/Chemical Parameters		
Water Solubility	α: 0.33 mg/L (22ºC); 0.53 - 2.3 mg/l β: 0.32 mg/L (22ºC); 0.28 - 31 mg/l	MRID 414215-02 (1st value for each isomer); Montgomery (1993); Guerin & Kennedy (1992)

Table 1: Summary of Environmental Chemistry and Fate Properties of Endosulfan (See Text for Discussion)

Parameter	Value	Reference/Comments *
Vapor pressure	˝-endosulfan: 1.5×10^{-5} torr (25°C); 3.0×10^{-6} mm Hg ˇ-endosulfan: 6.9×10^{-7} torr (25°C); 7.2×10^{-7} mm Hg	MRIDs 414215-01 (1st value for each isomer); 400606-01 (s)
Henry's Law Constant	˝: 1.01×10^{-4} to 6.65×10^{-5} atm m³/mol ˇ: 1.91×10^{-5} to 8.80×10^{-6} atm m³/mol	Montgomery (1993); Rice et al (1997a, 1997b)
Octanol/Water Partition, Log K_{ow}	˝: 4.74; 3.13 to 3.55 ˇ: 4.79; 3.62	MRID 414215-03 (1st value for each isomer); Montgomery (1993); McConnell et al (1998)

	Persistence	

Parameter	Value	Reference/Comments *
Hydrolysis $t_{1/2}$ pH 5 pH 7 pH 9	stable (>200 da) 11 da (˝);19 da (ˇ) 4 hr (˝); 6 hr (ˇ)	MRID 414129-01 (c)
Photolysis $t_{1/2}$ in water	stable, based on absorption spectrum	Waiver requested
on soil	stable	MRID 414307-01 (c)
Soil metabolism Aerobic $t_{1/2}$, days	˝-endosulfan: 35-67 (5 soils); mean=49, median=40, 90% CI on mean =57 ˇ-endosulfan: 104-265 (5); mean=163, median=125, 90% CI on mean =208 ˝+ˇ isomers: 75-125 (5); mean=99, median=86, 90% CI on mean =113 ˝-, ˇ-, and endo sulfate: 288-2148 (5); mean=798, median=392, 90% CI on mean = 1279	MRID 438128-01 (s)
Soil metabolism Anaerobic $t_{1/2}$. days	˝-endosulfan: 105-124 (2 soils) ˇ-endosulfan: 136-161 (2 soils) combined isomers: 144-154 endosulfan sulfate: 120	MRID 414129-04 (s)
Aquatic metabolism Aerobic	Supplemental studies indicate short residence time in water column, sorption onto sediment and plants, with slow release back into water.	MRID 449178-01 (u) Barry and Logan (1998) Cotham and Bidleman (1989)
Anaerobic	NA	NA
Major Transformation Products Identified in the Fate Studies:	endosulfan sulfate endosulfan diol	

	Mobility/Adsorption-Desorption	

Parameter	Value	Reference/Comments *
Batch Equilibrium	˝-endosulfan: K_d 66-320 ml/g (4 soils); K_{oc} 10,600 ml/g ˇ-endosulfan: K_d 77- 428 ml/g (4 soils); K_{oc} 13,500 ml/g endo-sulfate: expected to be similar in mobility to the parent endo-diol: expected to be more mobile	MRID 414129-06 (s) Gorlitz (1988a, b)

Table 1: Summary of Environmental Chemistry and Fate Properties of Endosulfan (See Text for Discussion)

Parameter	Value	Reference/Comments *
Field Dissipation		

Terrestrial Dissipation
    $t_{1/2}$ in soil surface layer,
    encompassing movement
    as well as degradation
	″-endosulfan: 46 da (GA tomato), 70 da (CA cotton), 6-11 da (CA cotton)
	˘-endosulfan: 90 da (GA tomato), 103 da (CA cotton), 19-63 days (CA cotton)
	<u>combined isomers</u>: 155-172 da (GA tomato), 89-93 da (CA cotton)
		MRID 413097-02
		MRID 414686-01
		MRID 430697-01

Bioaccumulation		
Accumulation in Non-target Aquatic Organisms	600X in mussels with depuration half-life of 34 hr 2429X for edible tissue and 2755X for whole body of mullet (*Mugil cephalus*); depuration within 48 hr	ACC. No. 05003053 (s) ACC. No. 05005824 (s)

* (c) = core study that fulfills guideline requirement; (s) = supplemental study; (u) = unacceptable study

Persistence

Chemical Degradation Processes

The rate of hydrolysis of ″- and ˘-endosulfan is pH dependent. While both isomers are stable at pH 5 (the study was not conducted for a sufficient period of time to specifically quantify the reported half-life of >200 days), they degrade at pH 7 with a half-life ($t_{1/2}$) of 19 days for ″-endosulfan and 11 days for ˘-endosulfan, and at pH 9 with a $t_{1/2}$ of 4 and 6 hours, respectively (MRID 414129-01). Open literature studies reported hydrolysis half-lives of 88 to 93 days at pH 4.5 and 24 to 28 days at pH 7 (Singh et al, 1991; Cotham and Bidleman, 1989). These studies were conducted at a higher temperature (30°C instead of 25°C), which may have influenced the rate of hydrolysis. Endosulfan diol was the major transformation product observed at pH's 7 and 9. Concentrations of endosulfan diol increased in time, but the study was not conducted for sufficient time to establish a pattern of decline for the diol.

Photolysis is not expected to be a route of dissipation for endosulfan or its major transformation products. The chemicals showed no significant absorption peaks in the visible light (290-800 nm) region of the spectra which would indicate vulnerability to breakdown by light. In a soil photolysis study conducted on a pH 6.4 silt loam, the isomers had a similar degradation profile whether exposed to light or kept in a dark control (MRID 414307-01).

Microbially-mediated Processes

In aerobic soil metabolism studies conducted on five soils (three from Germany, one from Mississippi, and one from Georgia), half-lives ranged from 35 to 67 days for ″-endosulfan and from 104 to 265 days for ˘-endosulfan. Four soils were acidic (pH 5.0 - 5.8), and thus not expected to favor hydrolysis, while one German soil was neutral (pH 7.1). The major observed transformation product, endosulfan sulfate, increased with time and appears to be more persistent than the parent (maximum levels ˘ 52% of the applied in all cases). The estimated half-lives for the combined toxic residues (endosulfan plus endosulfan sulfate) ranged from approximately 300 days to greater than 2000 days

(MRID 438128-01). Endosulfan lactone and endosulfan diol were only minor components (10%) in aerobic soils. Endosulfan diol, found in the hydrolysis studies, may not have been found in the aerobic soil metabolism studies because (a) the soils were acidic while the transformation product forms under alkaline hydrolysis; (b) it degrades too rapidly in the soil environment to be detected in large amounts at any time point; or (c) it is not a typical aerobic soil metabolism degradate. Although no studies were conducted with alkaline soils, endosulfan's susceptibility to hydrolysis at high pH values suggests that it will be less persistent in alkaline soils than in acidic to neutral soils.

The persistence of endosulfan appears to increase under anaerobic conditions. Anaerobic soil metabolism studies were conducted on German sandy loam (pH 7.2) and Mississippi silt loam (pH 6.4) soils that were flooded after 24 days of aerobic incubation. ″-Endosulfan degraded with half-lives of 105-124 days, compared to 136-161 days for ˘-endosulfan (MRID 414129-04). No degradates were produced at concentrations ˘ 10% of the applied during anaerobic conditions. Endosulfan sulfate, formed during the aerobic phase of the study, decreased under anaerobic conditions from 35% (German sandy loam) and 19% (Mississippi silt loam) to 22% and 15%, respectively.

In an aerobic aquatic metabolism study conducted in neutral to alkaline waters and sediments, 50 percent of the total ″- and ˘-endosulfan dissipated within approximately 2 weeks (MRID 449178-01). The DT_{50} for combined toxic residues (both parent isomers plus endosulfan sulfate) was approximately 3 weeks. Endosulfan is expected to be more persistent in acidic to neutral systems.

Endosulfan residues dissipated from seawater (pH 8.0-8.2) with half-lives on the order of days. The half-lives were similar in sterilized and unsterilized seawater, suggesting that hydrolysis, rather than metabolism, was the major route of dissipation. In the combined seawater-sediment system (pH 7.3-7.7), half-lives ranged from 1 to 3 weeks (Cotham and Bidleman, 1989). This indicates that binding to sediment is expected to be a competing route of dissipation from water bodies.

Mobility

Adsorption/Desorption

Batch equilibrium studies suggest that ″- and ˘-endosulfan have a high affinity to sorb to soil, reducing their potential mobility (MRID 414129-06). For ″-endosulfan, K_d values in four soils ranged from 66 to 320 ml/g, and the average K_{oc} was 10,600 ml/g (std. dev.= 2100 ml/g). For ˘-endosulfan, K_ds ranged from 77 to 428 ml/g, and the average K_{oc} was 13,600 ml/g (std. dev. = 2600 ml/g). Isotherms were linear over the narrow concentrations range used in this study (0.02 to 0.16 mg/l); however, the concentration range may have been insufficient to adequately characterize the isotherms across a realistic range of environmental concentrations. Therefore, the predictive value of the K_{oc} model is uncertain for endosulfan concentrations in the environment that fall outside of the study range.

While no mobility studies for endosulfan sulfate or endosulfan diol have been submitted that fulfill the Agency guidelines, studies conducted for European registration provide a general indication of the mobility of these transformation products relative to the parent. In a study conducted on the same four soils as the guideline study for the parent (MRID 414129-06), endosulfan sulfate had K_{oc} values ranging from 5,700 to 11,400 while endosulfan diol had K_{oc} values of 720 to 1,200 (Gorlitz, 1988b). While these studies would not fulfill EPA guidelines, they indicate that endosulfan sulfate will likely be

of similar mobility as endosulfan, while endosulfan diol is likely to be more mobile.

Volatility and Atmospheric Transport

Vapor pressures for endosulfan are on the order of 10^{-6} to 10^{-7} mm Hg. Henry's law constants (unitless) are on the order of 10^{-3} for α-endosulfan and 10^{-4} for β-endosulfan (Rice et al, 1997a, 1997b; Guerin and Kennedy, 1992), which indicate that endosulfan is semivolatile in water. In a supplemental laboratory volatility study on soil, about 5% of the total endosulfan was lost from a flask after 45 days of incubation at 40°C. However, the study could only account for 50% of total endosulfan. Rudel (1997) found that endosulfan volatilized from plant surfaces (60% dissipation within 24 hours) more rapidly than from soil surfaces (12% dissipation within 24 hours) in wind tunnel experiments. One potential reason for the increase in volatility from plant surfaces in comparison to soil surfaces may be that sorption of endosulfan onto soil particles may be a competing process.

Published literature (see Appendix B) provides evidence that endosulfan moves off site by atmospheric transport. Endosulfan has been detected in a variety of off-target locations, including rain and snow in the mountains of California (McConnell et al, 1998), air in the Canadian and Russian Arctic (Halsall et al, 1998), and surface water and snow in the Chesapeake Bay watershed (Lehotay et al, 1998). Long-range off-site transport may be resulting from vaporization of endosulfan, transport of dust particles on which endosulfan is adsorbed, or a combination.

Field Dissipation

Terrestrial Dissipation

The purpose of the terrestrial field dissipation studies is to see the chemical's fate under actual use conditions. The terrestrial field dissipation studies submitted by the registrant generally followed the pattern predicted by the laboratory studies. Endosulfan and its residues appeared moderately persistent. The studies were conducted in acidic to slightly acidic soils, which did not allow to assess the effect of the hydrolysis in the field.

Three terrestrial field dissipation studies submitted by the registrant were conducted on paired bare ground and cropped fields. One study was conducted on tomatoes in Georgia and two were conducted on cotton in California. Table 2 summarizes the results.

Table 2: Summary of Field Dissipation Studies for Endosulfan.

Study Location	Donaldsonville, Georgia		Tulare County, CA		Poplar, CA	
Formulation	Thiodan 3EC		Thiodan 3 EC		Thiodan	
Applic. Rate	0.5 lb a.i./A x 5 (7 day)		1.5 lb a.i./A x 2 (28 day)		1.5 lb a.i./A x 2 (29 day)	
Soil series/pH	Tifton sandy loam / 5.4		Unknown loam / 6.7		Unknown loamy sand / 6.8	
Rainfall/Irrig., 1st Month (in)	~ 6.5 inches		Furrow irrigation, greater than normal		~ 16 inches	
Plot/Crop	bare ground	tomatoes	bare ground	cotton	bare ground	cotton

Table 2: Summary of Field Dissipation Studies for Endosulfan.

Study Location	Donaldsonville, Georgia		Tulare County, CA		Poplar, CA	
˝-endosulfan $t_{1/2}$, da	47	46	71	69	6-11	6-7
max. leaching	35-66 cm	35-66 cm	35-65 cm	35-65 cm	15-31 cm	15-31 cm
˘-endosulfan $t_{1/2}$, da	100	91	101	106	23-36	19-63
max. leaching	35-66 cm	35-66 cm	35-65 cm	35-65 cm	15-31 cm	31-46 cm
Total ˝- and ˘-isomers $t_{1/2}$, da	90	76	89	93	44	41
Total endosulfan residues[1] $t_{1/2}$, da	172	155	147	142	100	97
endosulfan-SO_4 max. leaching	35-66 cm	5-35 cm	35-65 cm	35-65 cm	15-31 cm	31-46 cm

[1] Total endosulfan residues include both isomers plus endosulfan sulfate.

Although dissipation rates between the field studies span an order of magnitude, such variations are common and may result from differences in rainfall and irrigation, soil and air temperature and other meteorological conditions, pH, soil texture, soil microbial activity, crop type, and application rate. Dissipation half-lives are similar for bare-ground and cropped plots at each site, suggesting that neither foliar degradation nor canopy effects are major factors affecting dissipation of the chemical. All three sites had slightly acidic soil pH values, so hydrolysis was probably not a major route of dissipation. Dissipation rates from the soil surface in the field studies reflect a combination of degradation, transport, and uptake processes. Material balances in field studies are typically much lower than in the laboratory studies using radiolabeled materials, which can affect the amount of material that is recovered over time. Despite these limitations, dissipation of endosulfan in the field studies was within the same magnitude as would be predicted from laboratory soil metabolism studies.

Detections of endosulfan residues were sporadic and low at the reported depths of maximum leaching. In general, ˝ - and ˘ -endosulfan did not show definite patterns of substantial leaching. While the field studies were not specifically designed to track mobility with depth, the sporadic results could be indicative of movement of endosulfan along preferential flow paths in the soil.

Runoff: In a runoff study conducted on cotton in Kentucky (MRID 449036-01), endosulfan concentrations in runoff water were highly variable among buffer widths, making it difficult to draw definitive conclusions on the effectiveness of runoff buffers in reducing endosulfan concentrations reaching surface water. Endosulfan was applied to the cotton at 3 monthly applications of 1 lb ai/A each. A rainfall simulator added 1.2 inches of water per hour for 2 hours on the day after each application and following post-harvest cultivation. After the first rainfall simulation, the concentration of endosulfan in the edge-of-field runoff was greatest with 50-foot buffer and least with the unbuffered plot. During the second and third runoff events, the anticipated trend of decreasing endosulfan load with increasing buffer width was observed. The percentage of the applied endosulfan collected in runoff waters ranged from 3 to 8 percent from the unbuffered field; 4 to 6 percent from the field with the 25-foot buffer; and 5 to 7

percent from the field with the 50-foot buffer. From 43 to 83 percent of the transported endosulfan was adsorbed onto sediment.

An earlier runoff study was conducted on a cotton field in Chester County, South Carolina (MRID 413097-01), with soils that would typically favor infiltration rather than runoff. Irrigation used to simulate rainfall was not applied at a rate sufficient to generate significant runoff. Surface dissipation half-lives ranged from 25 to 44 days for ˝-endosulfan, 72 to 83 days for ˘-endosulfan, and 45 days for endosulfan sulfate. While the study might suggest that when endosulfan is applied to a soil that is not particularly prone to runoff and is exposed to rainfall that is not intense enough to result in significant runoff, a 200-foot buffer may result in reductions in endosulfan concentrations of up to two orders of magnitude, the flaws make it difficult or impossible to apply this study to other areas. Results from the Kentucky study indicate that the runoff buffer isn't always effective in reducing endosulfan concentrations.

Foliar Dissipation: Willis and McDowell (1987) summarized seven studies which evaluated the foliar persistence of endosulfan on a variety of crops. Foliar half-lives ranged from 1 to 5 days on a variety of crops (cotton, grapes, pears, tobacco, alfalfa, beets, and leafy vegetables) in studies conducted in California, Arizona, Kentucky, Canada, and Australia. The mean of the 8 reported half-life values was 3.2 days (standard deviation of 1.4 days). The upper 90th percent confidence interval value for the mean was 4 days. The reported results do not distinguish between foliar degradation, plant uptake, washoff, or volatilization as routes of dissipation. The majority of the studies did include rainfall events, suggesting that washoff may be one route of dissipation. Results reported by Rudel (1997), in which 54% of the endosulfan volatilized from plant surfaces within 24 hours of application, suggest that volatilization may be a major route of foliar dissipation in some instances. Total endosulfan residues (˝-, ˘-, and sulfate) dissipated from the leaves and fruit of tomato and pepper plants grown in Kentucky with half-lives ranging from 2 to 5 days (Antonious et al, 1998). The major routes of dissipation identified in this study were washoff after rain events and volatilization. The authors also noted that, as the plants grew, endosulfan residues become diluted by a greater plant surface area. While none of these studies were conducted according to guideline requirements and are considered supplemental information at best, they indicate that typical foliar dissipation rates for endosulfan will be on the order of days rather than weeks, and that washoff and volatilization appear to be major dissipation pathways. Thus, foliar dissipation rates can be expected to be slower during drier or cooler weather and more rapid under rainy or hotter weather.

Aquatic Dissipation: Although no aquatic field dissipation studies were conducted for endosulfan, a microcosm study that simulated a pond reported that endosulfan dissipated from the water column fairly rapidly, with a half-life of approximately 1 day (Barry and Logan, 1998). The simulation tanks were aerated, which may have increased volatilization losses, resulting in a more rapid dissipation rate than would be expected in natural water bodies. Major routes of dissipation noted in the study were sorption to sediment, degradation by bacteria, and uptake/sorption by macrophytes and algae.

A study submitted by the registrant in 1989 evaluated the fate and effects of endosulfan in two Georgia ponds adjacent to tomato fields (MRID 411641-01). This study provided supplemental information on the fate of endosulfan under these conditions. While the study was conservative in some aspects (for instance, the minimum distance of the treated fields to the pond ranged from 15 to 50 feet, less than the current 300-foot separation specified on the label), the watershed soils and rainfall/

irrigation rates were not necessarily conservative in terms of runoff potential. However, it does provide some useful information. The persistence of the isomers in the soil was sufficient to result in accumulations between applications and to contribute α- and β-endosulfan and endosulfan-SO$_4$ in runoff water at least five months after the last application. Endosulfan reached the pond via spray drift and runoff, with the highest concentrations in runoff occurring in the first event after the last application. Endosulfan sulfate in the pond resulted from runoff transport and transformation of the parent in the pond. Endosulfan dissipated rapidly from the water column of the ponds, apparently due to a combination of alkaline hydrolysis (pH of the ponds varied widely from 5.7 to 10) and sorption to sediment. Maximum concentrations of endosulfan isomers and endosulfan sulfate in the sediment were one to two orders of magnitude greater than that of the water column. Neither α- nor β-endosulfan were found in fish samples; however, endosulfan-sulfate was found at a maximum of 22.5 . g/Kg.

Accumulation

The reported K$_{ow}$ values of 55,500 for α-endosulfan and 61,400 for β-endosulfan suggest a relatively high potential to bioaccumulate in fish. However, supplemental studies suggest that endosulfan does not bioconcentrate at extremely high levels. In one study conducted with α-endosulfan on mussels, the bioconcentration factor for α-endosulfan was approximately 600X, with a depuration half-life of 34 hours (Acc. No. 05003053). In another study, conducted on striped mullet, the bioconcentration factors were ! 2400X for combined isomers in edible tissues (Acc. No. 05005824). In this study, endosulfan depurated after 24 hours. Tissue analysis in one study revealed the presence of endosulfan sulfate rather than α- and β-endosulfan.

Quality of Data

EPA has information in support of all environmental fate data requirements for endosulfan through a combination of core and supplemental studies and published scientific literature. While not all guideline requirements were met by specific studies supplied by the registrant, the Agency has been able to supplement its fate assessment with studies found in published literature. This data, along with available monitoring studies, provide a compelling assessment.

•	While the adsorption/desorption studies conducted on the α- and β-isomers did not span a wide range of concentrations, the results of the study are in general agreement with data reported in scientific literature. An available study on the mobility of the sulfate and diol degrades of endosulfan (MRID# 44346901) is of questionable validity. However, comparisons of Koc values for the parent and transformation products in German studies conducted on the same soil indicate that the sulfate transformation product will be of similar mobility and the diol degradate will be more mobile than the parent.

•	While a study submitted by the registrants provided only supplemental information on the aerobic and anaerobic aquatic metabolism of endosulfan, published literature help supplement in the assessment of the fate of endosulfan in aquatic environments.

•	Although EPA has no specific guideline studies on the persistence (hydrolysis, aerobic metabolism studies) of the toxic endosulfan sulfate transformation product, available studies indicate that it will be more persistent than the parent endosulfan. In addition, sufficient data is

available to calculate combined (both parent isomers plus endosulfan sulfate) half-lives.

• Two available supplemental studies on bioaccumulation in fish (Acc. No. 05003053 and 05005824) were not conducted according to current guidelines. While these studies have some deficiencies, they reflect results found elsewhere: endosulfan has the potential to accumulate in fish (bioconcentration factors of up to 2400X in edible tissue) but tends to depurate rapidly.

WATER RESOURCE ASSESSMENT

Overview

The environmental fate profile for endosulfan indicates that both the ˝- and ˘-isomers of endosulfan, as well as the endosulfan sulfate transformation product, may reach water resources. Existing water monitoring data confirm the presence of endosulfan residues in surface and ground water on a qualitative basis. Because endosulfan is persistent in neutral to acidic soils for months, the pesticide will be susceptible to transport via runoff for prolonged periods after initial application. With repeated applications, or even applications in consecutive years, endosulfan may accumulate in the soil, especially in acidic soils. Endosulfan is expected to be less persistent in alkaline soils due to its susceptibility to hydrolysis.

Its high affinity to sorb to soil indicates that endosulfan is likely to be associated predominantly with the sediment phase in runoff. Endosulfan reaching the water column, through spray drift or runoff, will have a propensity to sorb to benthic sediment, and this sediment may eventually become a source of endosulfan redistribution into the overlying waters. Because of its tendency to sorb onto soil, endosulfan should not be frequently detected in ground water; however, endosulfan is a persistent chemical, and available monitoring data has revealed endosulfan detections in wells. Aquifers below acidic soils are likely to be more vulnerable to endosulfan contamination than those below neutral or alkaline soils, due to the lack of hydrolysis under acidic conditions.

Endosulfan sulfate, the major transformation product identified in soil, is more persistent than the parent. Comparative studies indicate that endosulfan sulfate is similar in mobility to the parent endosulfan. The weight of evidence from available data suggests that endosulfan sulfate is a potential threat to the quality of both surface and ground waters.

Limited water monitoring data exist for endosulfan. The pesticide was not included in the U.S. Geological Survey National Water Quality Assessment (NAWQA) program. The STORET database includes a variety of monitoring reports for the endosulfan isomers and for endosulfan sulfate. The results reported in the database vary in terms of data quality, sampling and analytical methods, detection limits, and level of quality assurance/ quality control. Insufficient information exists with the reported studies to determine whether sampling occurred in actual endosulfan use areas or during times when endosulfan might potentially occur in water. Despite these limitations, the available studies have shown that endosulfan and endosulfan sulfate have contaminated numerous water bodies throughout the United States.

Ground Water Resources

While both α- and β-endosulfan appear to be persistent in most laboratory studies, particularly in acidic to neutral soils, its high affinity to sorb onto soils suggests that it should not move extensively through the soil and vadose zone to ground water. The Agency believes that the potential for endosulfan to reach ground water is limited to acidic to neutral soils and aquifers where preferential flow may be a prevalent pathway to ground water or where the ground water is shallow and is overlain by highly permeable soils. Available evidence suggests that the transformation products – endosulfan sulfate and endosulfan diol – may be persistent. Endosulfan sulfate is similar in mobility to the parent endosulfan while endosulfan diol appears to be more mobile.

The Pesticides in Ground Water Database (USEPA OPP, 1992) reports detections of endosulfan, ranging from trace to < 20 . g/L, in 1.3% of 2410 discrete samples (32 wells). Detections were reported in California, Maine, and Virginia. All sampling was conducted on or before the year 1989. The abbreviated nature of the PGWDB does not capture important factors such as depth of the water table, soil permeability, proximity of crops to wells, usage (application) of the chemical in the years prior to sampling, suitability of the analytical methodology used and/or limits of detection. Endosulfan sulfate was detected in 0.3% of the samples (6 out of 1969), with detections ranging from <0.005 to 1.4 . g/L. The detections were reported in Indiana and New York. Sampling occurred at or prior to 1990. No data were available for endosulfan diol.

Surface Water Resources

Endosulfan can contaminate surface water through spray drift or runoff. The persistence of α- and β-endosulfan is sufficient to expect accumulation on soil after repeated applications and possible accumulation from year to year. Such persistence suggests that endosulfan will be available to move to surface waters via runoff for several months or longer after application. Its high affinity to sorb onto soil indicates that endosulfan may move primarily while adsorbed to eroding soil and will preferentially partition into the sediment fraction of the surface water system.

Conditions which may favor runoff include poorly draining or wet soils with readily visible slopes toward adjacent surface waters, frequently flooded areas, areas overlaying shallow ground water, areas not separated from adjacent surface water with vegetated strips, and highly erodible soils cultivated using poor agricultural practices (such as conventional tillage).

Endosulfan sulfate is probably formed in the soil and, due to its very high persistence, is likely to reach surface waters as well. Endosulfan diol may be formed in neutral to basic surface waters as a hydrolysis product. Comparative studies indicate that endosulfan sulfate will be similar in mobility to β-endosulfan, and thus have an affinity to bind to sediment, while endosulfan diol is likely to be more mobile than the parent.

A review of the STORET data for α- and β-endosulfan, unspecified endosulfan residues, and endosulfan sulfate showed numerous detections. The STORET data is not reliable enough to enable an accurate quantitative assessment of the endosulfan distribution throughout the U.S., but it does give some insight into where endosulfan is being found. Confirmed detections of one or more endosulfan residues were reported in 38 states. States that reported relatively high numbers of endosulfan detections (with

respect to other reporting states) included California, Florida, Louisiana, Washington, Mississippi, and Ohio. An analysis of the monitoring data which reported detects for total endosulfan show a highly skewed distribution, as would be expected with monitoring data. The mean concentration is 0.17 µg/L, with a standard deviation of 0.98 µg/L. The 90th percentile value was 0.31 µg/L and the median value was 0.03 µg/L. The STORET concentrations are expected to be lower than peak EECs predicted by PRZM/EXAMS because they do not necessarily represent the most vulnerable sites or sampled peak times. Little is known about actual sample conditions. In addition, the limits of detection vary widely depending on the purpose of the monitoring and the availability of analytical methods and equipment. Thus, a reported nondetect does not necessarily mean that endosulfan didn't reach the water when it was applied. It could also mean that endosulfan was never applied where sampling occurred, that sampling took place at a time that missed the actual presence of endosulfan in water, or analytical methods failed to detect an actual presence of endosulfan in water.

The National Sediment Quality Survey (U.S. EPA, 1997) reported detections of endosulfan residues in stream sediments in 30 out of 76 watersheds in which endosulfan was analyzed. The watersheds occurred in 12 states, ranging from Rhode Island to California and from Mississippi to Michigan. As with the STORET data, one of the sources of data used in the survey, this summary provides more of a qualitative evaluation of the extent to which endosulfan may be found in the environment rather than a quantitative assessment of endosulfan occurrence.

Water Assessment for Ecological Effects

Surface water concentrations resulting from endosulfan application were predicted with PRZM coupled to EXAMS. In order to capture the widespread application uses of endosulfan, a range of crop scenarios was simulated. These scenarios were New York apples, Mississippi cotton, Tennessee lettuce, Georgia pecans, Maine potatoes, North Carolina tobacco, and Florida tomatoes. These particular crop uses represent approximately 70 percent of the total amount of endosulfan used. For each of the crop scenarios, predictions were developed for the following three application scenarios: 1) maximum labeled use rate along with the minimum allowable interval between applications, 2) maximum use rate with spray drift excluded, and 3) typical use rates using information supplied by BEAD. Typical and maximum rates are presented in Table 3. The prediction with the exclusion of spray drift was included to account for conditions in which spray drift buffers are used. Beginning in 1992, the end-use labels were revised to include buffer language stating: "Due to the risk of runoff and drift, do not apply within a distance of 300 feet of lakes, ponds, streams and estuaries."

The label language specifies only a 300-foot setback from the specified water bodies and does <u>not</u> specify a vegetative buffer. EFED's reasons for not considering potential runoff effects in the assessment include:

- A spray drift buffer is not necessarily a runoff buffer, which involves more than just shifting the application area 300 feet from the target. A runoff buffer must be specifically designed to reduce runoff and must be permanently planted in vegetation and properly maintained (see, for example, the USDA NRCS publication **Conservation Buffers to Reduce Pesticide Losses**, March 2000). The label does not specifically mention runoff buffer designs or the need to properly maintain the buffers.

- Runoff buffers are effective with sheet flow (which is roughly uniformly distributed) and not with concentrated flow, such as erosion channels, rills, and gullies. Thus, if not maintained, the buffer will not be effective (USDA/NRCS, 2000 publication).

- The 1999 Kentucky runoff study (MRID 449036-01, summarized in the Fate Assessment) showed that the runoff buffer wasn't always effective.

Table 3: Label Rates and Information For Endosulfan Uses Evaluated in the Environmental Risk Assessment.

Crop/Scenario Application Method	Labeled Applic. Rate (lb ai/A) x No. of Apps. Maximum/Typical [1]	Interval (days) [2] Minimum/Typical	Major Crop/Use Areas [3]
Cotton / MS Aerial	1.5 lb x 2 / 0.8 lb x 1	3 / 12	CA, AZ, TX, MS, LA
Apples / NY Ground Blast	1.5 lb x 2 / 1.5 lb x 1	10 / 10	NY, WA, MI
Tomatoes / FL Aerial	1 lb x 3 / 0.7 lb x 3	7 / 7	CA, TX, FL, OH, IN, MD, SC
Potatoes / ME Aerial spray	1 lb x 3 / 0.8 lb x 1	7 / 7	ND, MI, WI, ME, CO, ID, OR, PA, MN
Lettuce / TN [4] Aerial	1.5 lb x 2 / 0.7 lb x 2	2 / 9	CA, MI, AZ, TX, CO
Tobacco / NC Aerial	1 lb x 3 / 0.9 lb x 1	7 / 10	KY, GA, NC, TN, PA, FL
Pecans / GA Ground blast	1.5 lb x 2 / 0.9 lb x 2	as needed / 14	CA, GA, MS, TX

[1] The maximum single application rate and number of applications are specified on the label. The typical rate which has been used in exposure modeling in this section is based on information provided by BEAD, 2000.
[2] The interval between applications is not specified on most endosulfan labels. The intervals used for modeling came from information supplied by the Endosulfan Task Force or by BEAD, 2000.
[3] Major use areas are based on information supplied by BEAD (Quantitative Use Assessment) and by the Endosulfan Task Force presentation to OPP on 9/29/98 (compiled from Doane/Maritz data).
[4] Simulations in these states do not represent a major crop/use area for endosulfan, but likely represent more conservative estimates of EECs.

Approach to Calculating ˝- and ˇ-Endosulfan EECs: Because the ˝- and ˇ-isomers of endosulfan have different properties, EFED ran separate simulations for each isomer, adjusting the application rate to reflect the ratio of the isomer in the technical product (*i.e.*, 70% ˝-endosulfan and 30% ˇ-endosulfan). Chemical-specific input parameters used for the PRZM/EXAMS simulations are given in Table 4. PRZM input files are located in Appendix C.

Table 4. PRZM, EXAMS and SCIGROW Environmental Fate Input Parameters

Parameter	˝-endosulfan	ˇ-endosulfan
Molecular Weight	406.9	406.9
Solubility	530 . g/L	280 . g/L
Vapor Pressure	3.0×10^{-6} torr	7.2×10^{-7} torr
pH 7 hydrolysis half life	19 days	10.7 days
aqueous photolysis half life	stable	stable

Table 4. PRZM, EXAMS and SCIGROW Environmental Fate Input Parameters

Parameter	α-endosulfan	β-endosulfan
soil photolysis half life	stable	stable
aerobic soil metabolism half life	57 days (upper 90% c.i.) 49 days mean (SCIGROW)	208 days (upper 90% c.i.) 163 day mean (SCIGROW)
aerobic aquatic metabolism half life	114 days (2 x 57 day soil metabolism PRZM/EXAMS value)	416 days (2 x 208 day soil metabolism PRZM/EXAMS value)
EXAMS parameter PRBEN	0.5*	0.5*
anaerobic aquatic metabolism half life	286 days (2 x upper 90% c.i. of anaerobic soil study)	382 days (2 x upper 90% c.i. of anaerobic soil study)
soil organic carbon partitioning (K_{oc})	10600 L kg^{-1} (mean value PRZM/EXAMS) 11350 L kg^{-1} (median value SCIGROW)	13600 L kg^{-1} (mean value PRZM/EXAMS) 13900 (median value SCIGROW)

*PRBEN represents the fraction solute sorbed to runoff sediment that does not quickly equilibrate with the water column when the sediment enters the pond. The 0.5 value is an EFED standard for this parameter, and according to recent literature on sequestration of organics to sediments, this is a reasonable value.

*Calculating Endosulfan Sulfate EECs***:** Surface water EECs for endosulfan sulfate were estimated by a method that incorporated modeling and the EPA STORET database. First, the STORET database was searched for incidences where α - and β -endosulfan, and endosulfan sulfate were measured at the same time and at the same location. Those measurements with field codes that deemed the data unreliable were excluded, leaving 82 coincident measurements for surface water and 113 ground water. The ratio of endosulfan sulphate to total endosulfan (α plus β) was then calculated for each incidence. The median value for this ratio was 0.55 for surface water and 1.0 for ground water. This ratio was then multiplied by the surface water and ground water total (α plus β) EECs, as determined by PRZM/EXAMS, to obtain the endosulfan sulfate EECs. For example, for the Georgia pecan scenario with typical application rates (see example output files in Appendix C), the surface water acute EEC is 6.78 µg/L for α -endosulfan and 3.49 µg/L for β -endosulfan. Therefore, the predicted EEC for endosulfan sulfate is:

EEC   = total endosulfan x ratio of endosulfan sulfate to endosulfan
        = (6.78 µg/L +3.49 µg/L) x 0.55 = 5.65 µg/L

EEC Results. The resulting surface water EECs for the upper 1-in-10-year peak, the upper 1-in-10-year 21-day average and the upper 1-in-10-year 60-day average are shown in Tables 5a and 5b. Table 5 presents EECs when the labeled rate is used for cases with and without a spray drift buffer. Table 5 shows that spray drift accounts for 2 to 40% of the peak EEC values and about 7 to 40% of the average 21-day or 60-day EECs, depending on the crop scenario. Scenarios in high runoff areas (e.g., Florida tomatoes, Mississippi cotton) are only slightly affected by the addition of the spray drift buffers, whereas large reductions in EECs are apparent in other scenarios (e.g., New York apples). With typical use rates (Table 5), the EECs (for both acute and chronic) are 30 to 40% of the EECs with maximum use rate. It should be noted that the modeling for "typical" use rates assumes that no applications are made at any rate greater than the typical rate or at any frequency other than the typical. Thus, this approach is not conservative for those years or uses for which endosulfan may be applied at rates that are greater than "typical." The use of spray drift buffers further reduces these values, as Table 5 shows. While the increased distance between the area of application and the receiving water body is likely to reduce the amount of endosulfan that reaches the water body through runoff, the buffer is not specifically designed to be a runoff deterrent. The overall effectiveness as a runoff reduction cannot be quantified because unmaintained buffers may have little or no impact on the amount of runoff leaving the target fields. Two

runoff studies submitted by the registrant showed buffer effects ranging from a two-order of magnitude reduction on a soil that is not particularly prone to runoff with less intense rainfall to no reduction (no explanation provided for that result). Thus, OPP did not attempt to quantify any potential runoff reduction that may occur as a result of the spray drift buffer.

Table 5. Ecological risk assessment estimated environmental concentrations (EECs) for maximum labeled use rate (. g/L), with and without a 300-ft spray drift buffer, and typical use rate with a 300-ft spray drift buffer.

Scenario	Chemical	Maximum Label Use Rate w/o spray drift buffer			Maximum Label Use Rate with spray drift buffer			Typical Use Rate w/ spray drift buffer*		
		Peak	21-day avg	60-day avg	Peak	21-day avg	60-day avg.	Peak	21-day avg	60-day avg.
Apples	Total endosulfan	0.98	0.39	0.24	0.56	0.16	0.10	0.26	0.08	0.05
	Endosulfan sulfate	0.54	0.22	0.13	0.31	0.09	0.06	0.15	0.04	0.03
Cotton	Total endosulfan	7.53	3.16	2.51	7.89	3.18	2.57	3.01	1.12	0.82
	Endosulfan sulfate	4.14	1.74	1.38	4.34	1.75	1.42	1.65	0.62	0.45
Lettuce	Total endosulfan	5.01	2.16	1.27	2.99	0.91	0.51	1.39	0.42	0.24
	Endosulfan sulfate	2.76	1.19	0.70	1.65	0.50	0.28	0.77	0.23	0.13
Pecans	Total endosulfan	16.7	5.35	3.80	12.5	3.89	2.49	10.3	3.28	2.32
	Endosulfan sulfate	9.19	2.94	2.09	6.89	2.14	1.37	5.65	1.81	1.28
Potatoes	Total endosulfan	5.23	2.43	1.62	3.91	1.38	0.99	1.20	0.39	0.29
	Endosulfan sulfate	2.87	1.34	0.89	2.16	0.76	0.54	0.66	0.21	0.16
Tobacco	Total endosulfan	6.87	2.61	1.76	6.27	1.81	1.11	1.86	0.50	0.31
	Endosulfan sulfate	3.78	1.43	0.97	3.45	0.99	0.61	1.02	0.27	0.17
Tomatoes	Total endosulfan	19.1	6.50	4.87	18.6	6.11	4.54	13.0	4.25	3.16
	Endosulfan sulfate	10.5	3.57	2.68	10.3	3.36	2.50	7.14	2.34	1.74

*EECs for the typical use rate with spray drift buffer in place were estimated based on the assumption that the spray drift buffer would reduce the EEC in the same proportion as in the case in Table 5a for maximum label rate (i.e., PRZM/EXAMS runs were not actually made for the case of typical use rate with spray drift buffer).

Drinking Water Exposure Assessment

Drinking water EECs for surface and ground water were determined from PRZM/EXAMS and SCIGROW, respectively. EFED based the ΅- and ˘-endosulfan drinking water EECs for surface-water sources on PRZM/EXAMS simulations with the maximum allowable application of endosulfan (1.0 lb a.i. / acre, 3 times per year) to a Mississippi cotton scenario with the standard index reservoir and percent crop area factor (PCA) included. Procedures for calculating the EECs followed the method described in the section on water assessment for ecological effects: for the ΅- and ˘-endosulfan isomers, the output was adjusted by 70% for ΅-endosulfan and 30% for ˘-endosulfan; endosulfan sulfate concentrations were determined by multiplying the total endosulfan concentration by 0.55, the median ratio of endosulfan-sulfate to combined isomer concentrations found in the STORET database. Chemical-specific input parameters used for the PRZM/EXAMS simulations are given in Table 4; application-specific parameters for the cotton scenario used in the drinking water assessment are given in Table 6. All other parameters were used according to standard EFED practice. The input files for ΅- and ˘-endosulfan and the associated output files and EEC calculations are located in Appendix C. Both the peak and chronic surface water EECs are well within the range of measured endosulfan concentrations in the EPA STORET database (where total endosulfan concentrations range from less than the level of detection to greater than 180 . g/L). The groundwater EECs in Table 7 were generated with SCIGROW. For K_{oc}

values greater than 10,000 ml/g, SCIGROW gives the default value of 0.006 ppb, regardless of other input parameters. The default SCIGROW value is within the range of reported groundwater detections of 0 to 20 ppb (USEPA OPP, 1992). Table 7 summarizes the estimated drinking water EECs for the ˝ and ˇ isomers of endosulfan and the degradate endosulfan sulfate. These EECs are to be used for the human health risk assessment.

Table 6: Crop- and application-specific PRZM input parameters used for the surface drinking water assessment.

crop	cotton
application rate	70% of 1 lb a.i. acre
number of applications	3
application method	aerial
application dates	1-Jun, 9-Jul, 16-Aug [a]
spray efficiency	95%
spray drift	16% of mass applied to 1 acre at each application time
percent crop area	0.2 (cotton standard)

Table 7. Tier 2 EECs for Endosulfan and Endosulfan Sulfate in Drinking Water

Isomer	Surface Water Acute[a] EEC	Surface Water Chronic[b] EEC	Ground Water EEC
˝-endosulfan	3.5 . g/L	0.56 . g/L	--
ˇ-endosulfan	1.7 . g/L	0.24 . g/L	--
total endosulfan (˝ + ˇ)	5.2 . g/L	0.80 . g/L	0.006 . g/L
endosulfan sulfate	2.9 . g/L	0.45 . g/L	0.006 . g/L

[a] Acute EEC represents the upper 1-in-10 year peak concentration.
[b] Chronic EEC represents the upper 1-in-10 year mean annual concentration.

TERRESTRIAL EXPOSURE ASSESSMENT

Terrestrial exposure was evaluated using estimated environmental concentrations generated from a spreadsheet-based model that calculates the decay of a chemical applied to foliar surfaces for single or multiple applications. The model uses the same principle as the batch code models FATE and TERREEC for calculation of terrestrial estimated exposure concentrations (TEEC) on plant surfaces following application. Further explanation of the model is presented in Appendix D.

The terrestrial exposure assessment is based on the methods of Hoerger and Kenaga (1972) as modified by Fletcher *et al.* (1994). Terrestrial estimated environmental concentrations (EECs) for nongranular formulations (Table 8) were derived for major crops (apples, cotton, grapes, lettuce, pecans, potatoes, tobacco, and tomatoes) using current application rates and intervals between applications. Uncertainties in the terrestrial EECs are primarily associated with a lack of data on interception and subsequent dissipation from foliar surfaces. Willis and McDowell (1987) summarized seven studies which evaluated the foliar persistence of endosulfan on a variety of crops. Foliar half-lives ranged from 1 to 5 days on a variety of crops (cotton, grapes, pears, tobacco, alfalfa, beets, and leafy vegetables) in studies conducted in California, Arizona, Kentucky, Canada, and Australia. The mean of the 13 reported half-life values was 3.2 days (standard deviation of 1.4 days). The upper 90th percent confidence interval value for the mean (4 days) was used as the foliar dissipation rate for modeling purposes.

16

For pesticides applied as a nongranular product (*e.g.*, liquid, dust), the estimated environmental concentrations (EECs) on food items following product application are compared to LC_{50} values to assess risk. The predicted 0-day maximum and 56-day mean residues of a pesticide that may be expected to occur on selected avian or mammalian food items immediately following a direct single application at 1 lb ai/A and 3 lbs ai/A are presented in Table 8.

Table 8. Estimated environmental concentrations on avian and mammalian food items (ppm) following single applications at 1 lb ai/A and 3 lbs. a.i./A.

Application Rate	Food Items	EEC (ppm) Predicted Maximum Residue[1]	EEC (ppm) 56 Day Mean[1]
1 lb a.i./A	Short grass	240	27
	Tall grass	110	10
	Broadleaf/forage plants and small insects	135	11
	Fruits, pods, seeds, and large insects	15	1
3 lbs. a.i./A	Short grass	720	81
	Tall grass	330	31
	Broadleaf/forage plants and small insects	405	32
	Fruits, pods, seeds, and large insects	45	3

[1] Predicted maximum and mean residues are for a 1 lb ai/a application rate and are based on Hoerger and Kenaga (1972) as modified by Fletcher *et al.* (1994).

ECOLOGICAL EFFECTS ASSESSMENT

Appendix Table E-17 summarizes the 206 ecological toxicology studies submitted by the registrant for consideration: 22% were classified as acceptable and having provided useful information toward fulfilling the required guidelines. The remaining (78%) studies that did not pass the initial data screen are listed in Appendix Table E-18; data discrepancies are also listed. Many studies had been conducted prior to current Pesticide Assessment Guidelines; thus, their methodology could not be expected to conform entirely with present-day requirements. Although ecological effects were documented over a broad range of concentrations, toxicity estimates for species assemblages, *e.g.*, freshwater fish, were tightly clustered and thus consistent.

Toxicity testing reported in this section does not represent all species of bird, mammal, or aquatic organism. Only a few surrogate species for both freshwater fish and birds are used to represent all freshwater fish (2000+) and bird (680+) species in the United States. For mammals, acute studies are usually limited to Norway rat or the house mouse. Estuarine/marine testing is usually limited to a crustacean, a mollusk, and a fish. Also, neither reptiles nor amphibians are tested. The assessment of risk or hazard makes the assumption that avian and reptilian toxicities are similar. The same assumption is used for fish and amphibians.

Endosulfan is moderately toxic to honey bees, highly toxic to birds and mammals, and very highly toxic to freshwater and estuarine/marine fish and invertebrates. Table 9 provides a summary of the most sensitive ecological toxicity endpoints used in the hazard assessment of terrestrial animals and

Table 10 summarizes the most sensitive endpoints used in the hazard assessment of aquatic animals. No data were available to assess the toxicity of endosulfan to either terrestrial or aquatic plants. A more detailed discussion of the ecological toxicity studies that went into this assessment can be found in Appendix E. Additionally, 6(a)2 data indicate that the endosulfan diol degradate is highly toxic to aquatic organisms and open literature reports endosulfan sulfate is comparable to ˝ endosulfan in its toxicity to aquatic animals.

Table 9. Summary of acute and chronic toxicity data for terrestrial organisms exposed to endosulfan.

Species	Acute Toxicity				Chronic Toxicity	
	LD_{50} (ppm)	Acute Oral Toxicity (MRID)	5-day LC_{50} (ppm)	Subacute Dietary Toxicity (MRID)	NOEC/LOEC (ppm) (MRID)	Affected Endpoints
Northern bobwhite quail *Colinus virginianus*	--	--	805	moderately toxic (22923)	60 / 120 (402613-03)	--
Mallard duck *Anas platyrhynchos*	28	highly toxic (136998)	1053	slightly toxic (22923)	30 / 60 (402613-02)	reproduction and growth
Honey bee *Apis meliferus*	4.5	– (0001999)	--	--	--	--
Laboratory rat *Rattus norvegicus*	10	highly toxic (0038307)	--	--	15 / 75 (00148264)	growth

Endosulfan was highly toxic to mallard ducks (*Anas platyrhynchos*) and rats (*Rattus norvegicus*) on an acute exposure basis and moderately toxic to bobwhite quail (*Colinus virginianus*) on a subacute dietary basis. Chronic toxicity data on ducks (NOEC = 30) and rats (NOEC = 15) revealed that reproduction and growth were the most sensitive endpoints.

Table 10. Summary of acute and chronic aquatic toxicity estimates using technical grade endosulfan.

Species	Acute Toxicity			Chronic Toxicity	
	96-hr LC_{50} (. g/L)	48-hr EC_{50} (. g/L)	Acute Toxicity (MRID)	NOEC / LOEC (. g/L)	Affected Endpoints (MRID)
Rainbow trout *Oncorhychus mykiss*	0.8	--	very highly toxic (136999)	NOEC = 0.1[a]	--
Bluegill sunfish *Lepomis macrochirus*	1.7	--	very highly toxic (38806)	--	--
Fathead minnows *Pimephales promelas*	1.5	--	very highly toxic (Mayer & Ellersieck; 05008271)	NOEC = 0.2 LOEC= 0.4	Reduced growth and survival (05008271)
Scud *Gammurus lacustris*	--	6	very highly toxic (40094602)	NOEC = 0.07	--
Water flea *Daphnia magna*	--	166	very highly toxic (5008271)	NOEC = 2 LOEC < 7	reduced survival (5008271)

Table 10. Summary of acute and chronic aquatic toxicity estimates using technical grade endosulfan.

Species	Acute Toxicity			Chronic Toxicity	
	96-hr LC_{50} (. g/L)	48-hr EC_{50} (. g/L)	Acute Toxicity (MRID)	NOEC / LOEC (. g/L)	Affected Endpoints (MRID)
Striped bass *Mornone saxatillis*	0.1	--	very highly toxic (00001328)	0.01[a]	--
Eastern oyster *Crassostrea virginica*	0.45	--	very highly toxic (128688)	0.05[a]	--
Grass shrimp	1.3	--	very highly toxic (40228401)	--	--
Mussel	--	--	--	LOEC < 0.5	-- (05000047)

[a] chronic value predicted using acute to chronic ratio of 0.1 estimated from fathead minnow data (acute = 1.5 . g/L; chronic = 0.2 . g/L)

Acute aquatic toxicity estimates ranged from 0.1 to 166 . g/L for endosulfan. Estuarine/marine organisms generally were more sensitive to the effects of endosulfan than their freshwater counterparts. No chronic toxicity data were available for the most sensitive freshwater species, *i.e.*, rainbow trout (*Oncorhynchus mykis*) and scuds (*Gammurus lacustris*), thus acute to chronic ratio (0.1) was used to predict NOEC values for these species. The ratio, derived from fathead minnow data, was relatively nonconservative compared to the ratio (0.01) for invertebrates. On species where chronic toxicity data were available, *i.e.*, fathead minnows (*Pimephales promelas)* and water fleas (*Daphnia magna*), the most sensitive endpoints were reduced growth and survival. Acute toxicity data made available through 6(a)2 requirements (identification number L0000339) report an EC_{50} of 0.58 mg/L for endosulfan diol on *Daphnia magna*, indicating that this intermediate degradate is highly toxic to freshwater invertebrates.

Although open literature indicates that both isomers (˝ and ˘ -endosulfan) and endosulfan sulfate are toxic, EFED has no specific toxicity data with which to evaluate the toxicity of endosulfan sulfate. Thus, EFED requests that the following data be provided on the endosulfan sulfate degradate:

- Avian acute oral toxicity of bobwhite quail and mallard ducks (Guideline 71-1)
- Avian subacute dietary toxicity of bobwhite quail and mallard ducks (Guideline 71-2)
- Avian reproduction study (Guideline 71-4)
- Freshwater fish acute toxicity study of rainbow trout and bluegill sunfish (Guideline 72-1)
- Freshwater invertebrate acute toxicity study of Daphnia magna (Guideline 72-2)
- Freshwater fish full life cycle using rainbow trout (Guideline 72-5)
- Estuarine/marine fish acute toxicity study (Guideline 72-3)
- Estuarine/marine invertebrate acute toxicity study of mysid shrimp (Guideline 72-3)

Additionally, given the likely association of endosulfan with benthic sediments and the toxicity of endosulfan to aquatic organisms, EFED requests that the following data be provided on both technical grade endosulfan and the endosulfan sulfate degrade:

- Whole sediment acute toxicity testing using a freshwater invertebrate.
- Whole sediment acute toxicity testing using an estuarine/marine invertebrate

- Whole sediment chronic toxicity testing using a freshwater invertebrate.
- Whole sediment chronic toxicity testing using an estuarine/marine invertebrate.

ECOLOGICAL HAZARD ASSESSMENT

To evaluate the potential risk to nontarget organisms from the use of endosulfan products, risk quotients (RQs) are calculated from the ratio of estimated environmental concentrations (EECs) to ecotoxicity values. RQs are then compared to levels of concern (LOCs) used by OPP to indicate potential risk to nontarget organisms and the need to consider regulatory action (see Appendix F for more discussion). When available, field studies and incident data were used to substantiate EFED's concern of endosulfan's risk to nontarget organisms.

Nontarget Terrestrial Animals

The estimated environmental concentration (EEC) values used for terrestrial exposure are derived from the Kenaga nomograph, as modified by Fletcher *et al.* (1994), based on a large set of actual field residue data. The upper limit values from the nomograph represent the 95th percentile of residue values from actual field measurements (Hoerger and Kenega, 1972). The Fletcher et al. (1994) modifications to the Kenaga nomograph are based on measured field residues from 249 published research papers, including information on 118 species of plants, 121 pesticides, and 17 chemical classes. These modifications represent the 95th percentile of the expanded data set. Risk quotients are based on the most sensitive LC_{50} and NOAEC for birds (in this instance, mallard ducks and bobwhite quail) and LD_{50} for mammals (based on lab rat studies).

Acute and chronic risk quotients were calculated following the procedure outlined in Appendix F and were then compared to LOCs. Acute high risk, restricted use and endangered species LOCs are exceeded for birds (Table 11) and mammals (Table 12) at current application rates for the major crops modeled. Chronic LOCs for birds (Table 11) were exceeded (RQ range: 0.03 - 2.7) following both single and multiple applications on all food items except seeds. Chronic LOCs for mammals (Table 13) were exceeded (RQ range: 0.3 - 5.4) following multiple applications on all food items.

Table 11. Avian acute and chronic risk quotients for a single and multiple broadcast applications of nongranular products of endosulfan based on a bobwhite quail LC_{50} of 805 ppm and a mallard duck NOEC of 30 ppm.

Use/App. Method	Rate (Ibs ai/A) x No. Apps. (Interval, da)	Food Items	Max. EEC (mg/kg)[e]	Avg. EEC (mg/kg)[e]	Acute RQ ($EEC/_{LC50}$)	Chronic RQ (EEC/ NOAEC)
		Single Application				
tobacco (aerial), tomatoes (aerial), cantaloupe (ground)	1 lb./A (1)	Short grass	240	27	0.30[b]	0.9
		Tall grass	110	10	0.14[c]	0.3
		Broadleaf plants/Insects	135	11	0.17[c]	0.4
		Seeds	15	1	0.02	0.03
potatoes (aerial)	2 lbs./A (1)	Short grass	480	54	0.60[a]	1.8[d]

Table 11. Avian acute and chronic risk quotients for a single and multiple broadcast applications of nongranular products of endosulfan based on a bobwhite quail LC$_{50}$ of 805 ppm and a mallard duck NOEC of 30 ppm.

Use/App. Method	Rate (Ibs ai/A) x No. Apps. (Interval, da)	Food Items	Max. EEC (mg/kg)[e]	Avg. EEC (mg/kg)[e]	Acute RQ (EEC/LC50)	Chronic RQ (EEC/ NOAEC)
		Tall grass	220	21	0.27[b]	0.7
		Broadleaf plants/Insects	270	21	0.34[b]	0.7
		Seeds	30	2	0.04	0.07
Multiple Applications						
tobacco (aerial), tomatoes (aerial), cantaloupe (ground)	1 lb./A (3) 7-day interval	Short grass	332	81	0.41[b]	2.7[d]
		Tall grass	152	35	0.19[c]	1.2[d]
		Broadleaf plants/Insects	187	41	0.23[b]	1.4[d]
		Seeds	21	4	0.03	0.1
Apples (air blast), grapes (aerial), pecans (air blast)	1.5 lbs./A (2) 10-day interval	Short grass	424	81	0.53[a]	2.7[d]
		Tall grass	194	34	0.24[b]	1.1[d]
		Broadleaf plants/Insects	238	39	0.30[b]	1.3[d]
		Seeds	26	4	0.03	0.13

[a] exceeds acute high, acute restricted and acute endangered species LOCs.
[b] exceeds acute restricted and acute endangered species LOCs.
[c] exceeds acute endangered species LOCs
[d] exceeds chronic LOC
[e] estimated environmental concentrations predicted using 1st-order degradation model based on foliar dissipation.

Table 12. Acute RQ values for small (15 g), intermediate (35 g) and large (1,000 g) mammals feeding on short or tall grass, broadleaf plants/insects, and seeds exposed to endosulfan following single and multiple applications.

Site (method) Application Rate (number of applications)	Body Weight, g	RQ Short Grass	RQ Tall Grass	RQ Broadleaf Plants/Insects	RQ Seeds
tobacco (aerial), tomatoes (aerial), cantaloupe (ground) 1 lb a.i./A	15	23 [a]	10 [a]	13 [a]	0.32 [b]
	35	16 [a]	7.2 [a]	8.9 [a]	0.22 [b]
	1000	3.6 [a]	1.6 [a]	2.0 [a]	0.05
potatoes (aerial) 2 lbs a.i./A	15	69 [a]	31 [a]	26 [a]	0.64 [a]
	35	47 [a]	22 [a]	18 [a]	0.45[b]
	1000	11 [a]	4.9 [a]	4.0 [a]	0.03
tobacco (aerial), tomatoes (aerial), cantaloupe (ground) 1 lb. a.i./A (3)	15	32 [a]	14 [a]	18 [a]	0.44 [b]
	35	22 [a]	10 [a]	12 [a]	0.31 [b]
	1000	5 [a]	2.3 [a]	2.8 [a]	0.06

Table 12. Acute RQ values for small (15 g), intermediate (35 g) and large (1,000 g) mammals feeding on short or tall grass, broadleaf plants/insects, and seeds exposed to endosulfan following single and multiple applications.

Site (method) Application Rate (number of applications)	Body Weight, g	RQ Short Grass	RQ Tall Grass	RQ Broadleaf Plants/Insects	RQ Seeds
apples (air blast), grapes (aerial), pecans (air blast) 1.5 lbs. a.i./A (2)	15	40 [a]	18 [a]	23 [a]	0.55 [a]
	35	28 [a]	13 [a]	16 [a]	0.39 [b]
	1000	6.3 [a]	2.9 [a]	3.6 [a]	0.08

[a] exceeds acute high, acute restricted and acute endangered species LOCs.
[b] exceeds acute restricted and acute endangered species LOCs.
[c] exceeds acute endangered species LOCs

Table 13. Chronic RQ values for mammals feeding on short grass, tall grass, broadleaf plants/insects, and seeds exposed to endosulfan following multiple applications.

Site (method) Application Rate (number of applications)	RQ Short Grass	RQ Tall Grass	RQ Broadleaf Plants/Insects	RQ Seeds
tobacco (aerial), tomatoes (aerial), cantaloupe (ground) 1 lb. a.i./A (3)	4.4 [a]	2.3 [a]	2.7 [a]	0.3
apples (air blast), grapes (aerial), pecans (air blast) 1.5 lbs. a.i./A (2)	5.4 [a]	2.3 [a]	2.6 [a]	0.3

[a] exceeds chronic LOC

Nontarget Aquatic Animals

Surface water concentrations resulting from endosulfan application to major crops were predicted with PRZM coupled to EXAMS. Seven scenarios were simulated: cotton (Mississippi), potatoes (Maine), apples (New York), tobacco (North Carolina), tomatoes (Florida), lettuce (Tennessee), and pecans (Georgia). Tables 5a and 5b list the peak and 21-day estimated environmental concentrations for each of the major crops and their highest application rate. Peak EECs were then compared to acute toxicity endpoints to derive acute risk quotients and 21-day EECs were compared to chronic toxicity endpoints (NOEC) to derive chronic risk quotients for freshwater (Table 14) and estuarine/marine (Table 15) organisms. At the current application rates used on the major crops where endosulfan is employed, acute high risk, restricted use and endangered species levels of concern are exceeded for both freshwater and estuarine/marine organisms. Acute RQ values ranged from 1 - 23 for freshwater fish and from 0.17 - 3.3 for freshwater invertebrates. Estuarine/marine fish and invertebrates were roughly an order of magnitude more sensitive to the effects of endosulfan, with acute RQ values ranging from 9.8 to 191 for fish and 2 to 42 for invertebrates. Even using maximum application rates coupled with a 300-ft spray drift buffer (Appendix F, Tables F-13b, F-14b, and F-15b) and typical application rates coupled with 300-ft buffers (Appendix F, Tables F-13c, F-14c, and F-15c), RQ values for freshwater fish (range 0.3 - 16), freshwater invertebrates (range 0.05 - 2.2), estuarine/marine fish (range: 2.6 - 130) and estuarine/marine invertebrates (range: 0.6 - 29) still exceeded acute high risk, restricted use and endangered species LOCs. Chronic LOCs for freshwater fish (RQ range: 0.5 - 29), freshwater

invertebrates (RQ range: 1.1 - 61), estuarine/marine fish (RQ range: 5 - 316) and estuarine/marine invertebrates (range: 1.6 - 85) were also exceeded using typical application rates coupled with 300-ft spray drift buffers. **In general, the magnitude of the aquatic RQ values is high enough that reduced application rates and the use of buffers does not reduce the likelihood of exceeding either acute or chronic LOCs.**

Table 14. Acute and chronic risk quotients for freshwater fish (rainbow trout *Oncorhynchus mykiss*) and invertebrates (scud *Gammurus lacustris*) exposed to endosulfan

Crop Application Rate (# of apps)	EECs Peak / 21-day Average 56-day Average (ug/L)	Acute Risk Quotients		Chronic Risk Quotients	
		Freshwater Fish $LC_{50} = 0.83$. g/L	Freshwater Invertebrate $LC_{50} = 5.8$. g/L	Freshwater Fish $NOEC = 0.11$. g/L	Freshwater Invertebrate $NOEC = 0.07$. g/L
Apples 1.5 (2)	0.98 0.39 0.24	1.2[a] – --	0.17 – --	-- -- 2.2[b]	– 5.6[b] --
Cotton 1.5 (2)	7.5 3.2 2.5	9.1[a] – --	1.3[a] – --	– -- 23[b]	– 45[b] --
Lettuce 1.5 (2)	5.0 2.2 1.3	6.0[a] – --	0.9[a] – --	– -- 12[b]	– 31[b] --
Pecan 1.5 (2)	17 5.4 3.8	20[a] – --	2.9[a] – --	– -- 35[b]	– 76[b] --
Potato 1.0 (3)	5.2 2.4 1.6	6.3[a] – --	0.9[a] – --	- -- 15[b]	-- 35[b] --
Tobacco 1.0 (3)	6.9 2.6 1.8	8.3[a] – --	1.2[a] – --	– -- 16[b]	– 37[b] --
Tomato 1.0 (3)	19 6.5 4.9	23[a] – --	3.3[a] – --	– -- 44[b]	– 93[b] --

[a] exceeds acute high risk, restricted use, and endangered species LOCs   [b] exceeds chronic LOC

Table 15. Acute and chronic risk quotients for estuarine/marine fish (stripped bass *Morone saxatilis*) and invertebrates (Eastern oyster *Crassostrea virginica*) exposed to endosulfan

Crop Application Rate (# of apps)	EECs Peak 21-day Average .g/L	Acute Risk Quotients		Chronic Risk Quotients	
		Estuarine/marine Fish $LC_{50}=0.1$ .g/L	Estuarine/marine Invertebrate $LC_{50}=0.45$ .g/L	Estuarine/marine Fish NOEC = 0.01 .g/L	Estuarine/marine Invertebrate NOEC = 0.24 .g/L
Apples 1.5 (2)	0.98	9.8[a]	2.2[a]	–	--
	0.39	–	–	--	7.8[b]
	0.24	--	--	24[b]	--
Cotton 1.5 (2)	7.5	75[a]	17[a]	–	–
	3.2	–	–	--	63[b]
	2.5	--	--	251[b]	--
Lettuce 1.5 (2)	5.0	50[a]	11[a]	–	–
	2.2	–	–	--	43[b]
	1.3	--	--	127[b]	--
Pecan 1.5 (2)	17	167[a]	37[a]	–	–
	5.4	–	–	--	107[b]
	3.8	--	--	380[b]	--
Potato 1.0 (3)	5.2	52[a]	12[a]	–	–
	2.4	–	–	–	49[b]
	1.6	--	--	162[b]	--
Tobacco 1.0 (3)	6.9	69[a]	15[a]	–	–
	2.6	–	–	--	52[b]
	1.8	--	--	176[b]	--
Tomato 1.0 (3)	19	191[a]	42[a]	–	–
	6.5	–	–	--	130[b]
	4.9	--	--	487[b]	--

[a] exceeds acute high risk, restricted use, and endangered species LOCs
[b] exceeds chronic LOC

ENVIRONMENTAL RISK CHARACTERIZATION

Overview

A screening assessment for terrestrial impacts and a non-conservative refined assessment for aquatic impacts indicate that endosulfan is likely to result in acute and chronic risk to both terrestrial and aquatic organisms. This assessment is supported by monitoring data showing widespread contamination of surface water and incident data showing that endosulfan's current use represents a serious risk of non target mortality for aquatic species. EFED used probabilistic assessment techniques to conduct a more refined aquatic exposure assessment based on actual reported application rates in California coupled with a 300-ft spray-drift buffer. This refined assessment projects that on sites within the endosulfan use area that are vulnerable to runoff, mortality to nontarget fish is probable in any given year. This ranges from a 10% probability that 10% of all non target aquatic species in a population will suffer 50% mortality for the least vulnerable crop (apples) to a 90% probability that roughly 60% of all the aquatic species will suffer 50% mortality for the most vulnerable uses (tomatoes). Although the 300-foot buffer may provide

additional benefits in reducing runoff loads into surface water, it is not specifically designed to reduce runoff and studies conducted by the registrants showed mixed results. The assessment conclusions are supported by incident data which shows that multiple fish kill incidents attributable to endosulfan use are reported each year. While repopulation is likely through downstream migration from unaffected areas, the intermediate effect on food chains is uncertain. Based on the available toxicity data, incident data and a refined risk assessment, endosulfan represents a high acute risk to aquatic organisms.

Although EFED's screening level and refined risk assessments make assumptions about exposure and effects models, the assumptions for this assessment are not particularly conservative. EFED has focused primarily on aquatic risk; however, endosulfan is clearly a risk to terrestrial nontarget organisms as well. Additionally, the refined risk assessment addresses the probability and magnitude of acute effects. Given that chronic risk quotients are several orders of magnitude greater than acute values, endosulfan's capacity to act as an endocrine disruptor, and its persistence in terms of both the parent and its toxic degradates, the chronic impacts of endosulfan are likely to be significant. It is also important to note that likelihood of ecological effects is based on surrogate species considered representative of species found in areas where endosulfan is used. The sensitivity of the surrogate species may not however, be representative of the most vulnerable organisms. While EFED has attempted to account for a range of sensitivities in its more refined risk assessment, it remains uncertain whether the full distribution of effects has been captured.

Endosulfan is a broad-spectrum insecticide that has been used since the 1950s on a wide variety of crops across the United States. This ecological risk characterization is based on current label application rates and intervals for major crops on which endosulfan is used. At both maximum and "typical" (based on market share data) application rates, endosulfan is likely to result in acute and chronic risk to both terrestrial and aquatic species. Environmental monitoring studies demonstrate widespread contamination of surface water and confirm EFED's concern that endosulfan will likely contaminate both terrestrial and aquatic resources. Outside of incidents associated with organophosphate pesticides and carbofuran, endosulfan-related incidents account for the greatest percentage of nontarget mortality reported in EPA's Ecological Incident Information System and confirm EFED's expectation that endosulfan's current use represents a serious risk of nontarget mortality.   EFED has projected that even using nonconservative assumptions (*i.e*., "typical" application rates and a 300-foot spray drift buffer), current endosulfan use rates on 88% of the crops modeled will exceed acute high risk LOCs more than 99% of the time. In other words, in any given year, we would expect a high likelihood that nontarget fish mortality would result from endosulfan use. Indeed, this is confirmed by incidents reported in the EIIS, which show multiple incidents per year, even in the years since the buffer language was added to the label. Although incident reports confirm the likely acute effects that EFED expects based on exceedances for acute LOCs, chronic RQ values ranging as high as 487 also make it likely that endosulfan will inflict chronic effects. Given the reproductive and developmental effects of endosulfan, coupled with the chemical's ability to bind to the human estrogen receptor, these chronic effects could have a considerable impact on nontarget organisms.

Prevalence and Persistence in the Environment

Available laboratory and field studies clearly indicate that ΅- and ˘-endosulfan will persist in the soil, with half-lives on the order of months. The ˘-isomer is consistently more persistent than the ΅-isomer. Endosulfan is expected to be less persistent in alkaline (high pH) environments than in acidic to

neutral environments because of its susceptibility to alkaline hydrolysis. However, sorption onto soil, sediments, and plants may be a competing process that binds endosulfan for slow release at later times. The major transformation product, endosulfan sulfate, is more persistent in the environment than the parent. Available data suggest that endosulfan sulfate is similar in mobility to ˘-endosulfan and is a potential threat to the quality of both surface and ground waters.

Endosulfan has been detected in nearly all environmental compartments, including surface- and ground-water and in areas where it is not used (*e.g.*, the Arctic, mountains of California, and national parks). The widespread nature of endosulfan contamination is evident in the STORET data base, which reports detects of one or more endosulfan residue in 38 states. It is important to note that, as use patterns and pest pressures change, the potential for endosulfan to reach water bodies changes as well. Thus, we don't necessarily expect that endosulfan residues are actually present in water in all 38 states today, only that endosulfan is likely to be found in vulnerable water bodies wherever it is used. Major routes of transport appear to be spray drift and runoff (dissolved in water and attached to sediment) into surface waters, downward leaching through porous materials and preferential flow to ground water, and volatilization and atmospheric transport to off-target sites. Volatilization is likely to be a major route of dissipation under certain conditions, particularly when endosulfan is applied to plant surfaces when the air temperature is warm or hot. Volatilization losses are reduced when endosulfan reaches soil, as sorption becomes a competing process. However, as reported by Leys et al (1999), endosulfan sorbed to soil particles can be transported through windswept dust.

Its high affinity to sorb to soil indicates that endosulfan is likely to be associated predominantly with the sediment phase in runoff. Endosulfan reaching the water column, through spray drift or runoff, will have a propensity to sorb to sediment such that, with time, more of the pesticide will be associated with sediment than dissolved in water. Because of its tendency to sorb onto soil, endosulfan should not be frequently detected in ground water; however, available monitoring data include endosulfan detections in wells. Aquifers below acidic soils are likely to be more vulnerable to endosulfan contamination than those below neutral or alkaline soils, due to the lack of hydrolysis under acidic conditions.

Given endosulfan's expected behavior in water (expected short duration time as dissolved endosulfan in water, with preferential sorption to bottom and suspended sediment), most monitoring studies are unlikely to detect the peak concentrations of endosulfan resulting from runoff unless sampling occurs at least daily or is specifically timed to coincide with runoff events. In addition, many analytical methods for water filter the samples (and thus would filter out any endosulfan in suspended sediments) and thus are not likely to reflect total endosulfan load in the water column. The available monitoring data were such that they did not provide a meaningful assessment of the peak concentrations of endosulfan that may occur in aquatic ecosystems. Thus, OPP relied on incident data and modeling in its aquatic risk assessment. Acute mortality impacts occur from short-term exposure of aquatic organisms to endosulfan in water. The reported fish kills are evidence that endosulfan is indeed getting into water at concentrations that are sufficient to result in mortality.

Impact on Nontarget Organisms

Endosulfan is moderately toxic to bees, highly toxic to birds and mammals and very highly toxic to fish and aquatic invertebrates on an acute exposure basis. No data were available to assess the toxicity of endosulfan to either terrestrial or aquatic plants. The distribution analysis of 96-hr LC_{50}s for

freshwater organisms (including fish, molluscs and crustaceans) demonstrated a wide range of sensitivity to endosulfan, spanning 5 orders of magnitude. A single application at 1 lb a.i./A (lower than maximum label rates) is likely to result in acute high risk to both terrestrial and aquatic organisms. Additionally, the current use rates for endosulfan are expected to result in chronic toxicity to both terrestrial and aquatic nontarget organisms.

Except for birds feeding on seeds, acute endangered species LOCs are exceeded following a single application of endosulfan at 1 lb a.i./A. With multiple applications acute high risk, restricted use and endangered species LOCs are exceeded. Chronic LOCs are exceeded on all food items except seed with both single and multiple applications. Following single and multiple applications acute high risk, restricted use, endangered species, and chronic LOCs are exceeded for mammals. Similarly, all LOCs (acute high risk, restricted use, endangered species and chronic) are exceeded for both freshwater and estuarine/marine organisms. The latter are an order of magnitude more sensitive to the effects of endosulfan. In general, the magnitude of aquatic RQ values was high enough that reduced application rates and the use of buffers did not reduce the likelihood of exceeding either acute or chronic LOCs.

A total of 206 ecological effect studies were submitted to support the reregistration of endosulfan. Toxicity endpoints were consistent within species assemblages and provided compelling evidence of the toxicity of the technical grade (racemic mixture of ˝ and ˘ isomers) and its formulated end-products of endosulfan. EFED believes that existing studies clearly establish the toxicity of endosulfan and requests only that technical grade endosulfan be subjected to additional testing of its endocrine disrupting potential. Although open literature indicates that both isomers (˝ and ˘-endosulfan) and the endosulfan sulfate degradate are toxic, EFED has no specific toxicity data with which to evaluate the toxicity of endosulfan sulfate. The risk quotients calculated in this assessment did not account for the toxicity of endosulfan sulfate. While EFED believes that the additional toxicity studies specific to endosulfan sulfate would serve to demonstrate that the actual risks from the use of endosulfan and may indeed be even greater than predicted by the risk quotients in this document, its risk assessment demonstrates that adverse risk, including mortality, can be expected based solely on the toxicity of the parent.

Likelihood of Exceedences

As an initial screen of endosulfan, EFED has used Monte Carlo simulations to estimate the probability that the acute high risk level of concern for freshwater fish will be exceeded using the current application rates for endosulfan on the eight crops discussed previously. Based on the distribution analysis of acute freshwater fish RQ values (Appendix H), the probability that RQ values will exceed the acute high risk LOC is greater than 99% for seven out of the eight modeled crops. It is noteworthy that the distribution analyses were based on estimated environmental concentrations for ˝-endosulfan only and that EECs would likely have been be higher had ˘-endosulfan and endosulfan sulfate been included. Additionally, the LC_{50} distribution was based on acute freshwater fish toxicity estimates; acute toxicity estimates for estuarine/marine fish were roughly an order of magnitude more sensitive. Thus, while Monte Carlo simulations for freshwater fish RQ values are not conservative, on 6 out of the 7 crops modeled, the probability of exceeding high acute risk LOCs for freshwater fish is greater than 99%.

Incidents

Endosulfan is among the most frequently reported causes of aquatic incidents for pesticides. Consistent with EFED's expectation that current use patterns of endosulfan represent a threat of both acute and chronic toxicity, incident data (91 reported cases) confirm impacts on terrestrial and aquatic organisms. Given the acute aquatic RQ values ranging from 3 to 199 for maximum application rates and from 2 to 139 for typical application rates for tomatoes, it is not surprising that incident data exist for this use.

A review of the Ecological Incident Information System (EIIS; US EPA, 1994) revealed that since 1971, the cyclodiene class insecticides accounted for the third highest percentage (5% of the reported incidents) of reported incidents, behind the organophosphate pesticides (28%) and carbofuran (11%). Endosulfan, with 91 reported incidents, accounted for majority (62%) of those cyclodiene incidents (Appendix G, Table G1). The majority of incidents occurred in California, South Carolina, North Carolina, and Louisiana (Appendix G, Table G2). The overwhelming majority (96%) of the incidents were associated with the aquatic environment: 82% affected fish while 7% affected aquatic macroinvertebrates (Appendix G, Tables G3 and G4). An analysis of incidents associated with organophosphates indicates that California and Louisiana are among the leading states with reported incidents. It is unknown whether the similarity between incidents for organophosphate pesticides and endosulfan is reflective of an intrinsic reporting bias or whether the data are representative of the actual incident rate. However, EFED assumes that any geographical reporting bias applies across all chemicals such that no one chemical is likely to be singled out. Thus, while the EIIS may not reflect an unbiased estimate of incidents, minimally it is useful for documenting ecological field effects that substantiate EFED concerns about nontarget mortality.

The database indicates that 34% of the endosulfan incidents were a result of either accidental or intentional misuse of the pesticide, 29% resulted from the labeled use of endosulfan (Appendix G, Table G5), and the rest were unspecified. Approximately 32% of the incidents were directly attributable to runoff (Appendix G, Table G7). However, weather conditions were not specified in the majority of cases, so that the contribution of runoff may well be underestimated by the reported results. All but 15 of the incidents were attributable to agricultural uses; roughly equal percentages (10%) of the total number of incidents were associated with lettuce, tomatoes, and tobacco (Appendix G, Table G6). In incidents reported on birds, the average kill was nearly 27,000 birds and ranged as high as 39,970 birds. For fish, endosulfan-related incidents averaged 5,090 killed and ranged as high as 240,000 fish. Incidents involving plants averaged 833 plants per incident, ranging up to 2,000 plants affected (Appendix G, Table G8). It should be noted however, that one of the incidents involving black birds was the result of intentional misuse; the remaining incidents involving ducks were a result of undetermined cause and only had a certainty index of possible.

In states where endosulfan-related incidences were most frequently reported, *i.e.*, California, North Carolina, South Carolina and Louisiana, frequency distributions show no real pattern with time across states (Figure 2). The number of incidents peaked at 8 in 1976 in California, but additional incidents were reported as recently as 1996. In South Carolina, the maximum number of incidents reported (5) peaked in 1980 whereas in North Carolina the peak (4) occurred in 1992. In Louisiana, the peak (4) occurred in 1996. In 1984 the California Department of Food and Agriculture (CDFA memo 84-85) proposed permit conditions for the use of endosulfan to reduce the hazards of fish-bearing waters
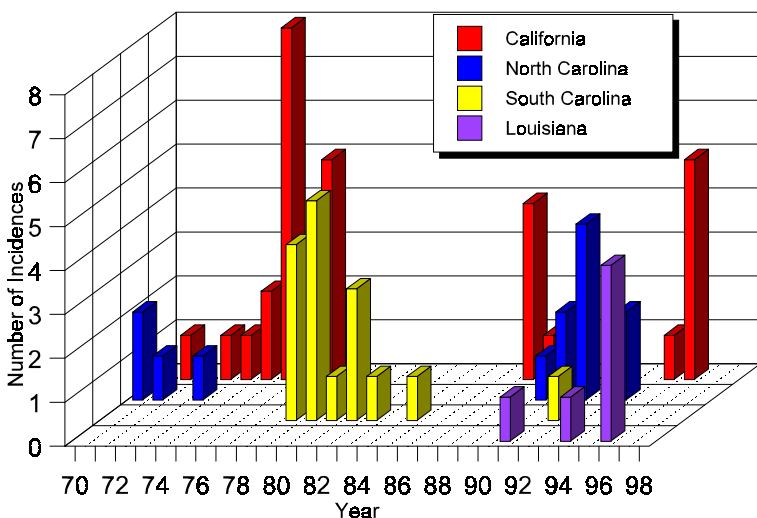
Figure 2. Frequency distribution of endosulfan-related incident reports for California, North Carolina, South Carolina, and Louisiana over the years 1970 to 1998.

that were evidenced through annual aquatic incidents. Additional permit restrictions were suggested in 1991 to curb exceedances of water quality criteria that were considered likely to result in the degradation of aquatic environments (CDFA memo ENF 91-12). As Figure 2 demonstrates however, endosulfan-related incidents have continued in California in spite of the recommended permit restrictions. Reported incidents in California since 1984 have been confined to the aquatic environment and only 2 out of the reported 11 incidents have been associated with misuse (Appendix Table G10). It is also significant to note that fish kill incidents have continued in the remaining states since a 300-ft spray-drift buffer was added to endosulfan technical labels. Thus, despite use restrictions to limit degradation of the aquatic environment, endosulfan has continued to access the aquatic environment and result in nontarget mortality.

According to the National Oceanic and Atmospheric Agency's fish-kill database (Pait *et al*, 1992), endosulfan was responsible for more fish kills in U.S. estuaries and coastal rivers between 1980 and 1989 than all currently used pesticides at that time. The report noted that endosulfan was one of the most often found of the inventoried pesticides in aquatic biota and in one case affected estuarine biomass. Monitoring of endosulfan residues (α- and β-endosulfan and endosulfan sulfate) in the Chesapeake Bay estuarine system as recently as 1997 (Lehotay *et al.* 1998) revealed that in 8 of the 10 months sampled, endosulfan exceeded EPA's freshwater criteria of 56 ng/L, with detections as great as 225 ng/L. In the other two months, endosulfan residues were detected but were not quantified. Although water column concentrations fluctuated widely throughout the sampling period, endosulfan residues were readily detected in oysters collected from the same sites and remained relatively constant throughout the year. Endosulfan sulfate averaged roughly 54% of the total residues. Lehotay et al (1998) expressed concern that endosulfan residues were detected in both water and oysters many months after agricultural application and underscored the chemical's persistence. Peak residues in water were roughly double the LC_{50} of striped bass and 5 times the LOEC of estuarine/marine organisms. Additionally, monitoring of endosulfan residues in mussels (Wade *et al.* 1998) from 1994 through 1997 has reported α-endosulfan concentrations ranging from 9 - 89 ng/g; these tissue residues are orders of magnitude greater than exposure concentrations resulting in both chronic and acute toxicity to oysters.

The high frequency of reported incidents for endosulfan is consistent with EFED's concern that there is risk of acute toxicity following acute exposure based on RQ values exceeding acute high risk, restricted use and endangered species levels of concern. However, these incidents reflect acute effects of endosulfan and do not provide any information on the associated chronic effects. With chronic RQ values ranging as high as 14 for terrestrial organisms and 1,414 for aquatic organisms, it is likely that

chronic effects have occurred and are in part evident in the endocrine disrupting effects discussed below.

Mutagenicity

Based on the results of sex-linked recessive lethal (SLRL) and sex chromosome loss (SCL) tests on fruit flies (*Drosophila melanogaster*), endosulfan has been demonstrated as a mutagen in insects (Velázquez *et al.* 1984). The mutagenic effect of endosulfan has also been linked to blood cell changes observed in mammals (Sylianco 1978; Usha Rani *et al.* 1980).

Endocrine Disruption

Exposure to endosulfan has resulted in both reproductive and developmental effects in nontarget animals (Appendix J). Amphibians exposed to endosulfan exhibited impaired development of tadpoles into adults (Berrill *et al.* 1998). In birds, endosulfan impaired the development of the genital tract (Lutz and Lutz-Ostertag 1975). In mammals, endosulfan reduced hormone levels (Wilson and LeBlanc 1997), produced testicular atrophy (NCI 1978; Gupta and Gupta 1979) and reduced sperm production (Dalsenter et al. 1999). Additionally, endosulfan has been demonstrated to bind to the human estrogen receptor and exhibit significant estrogenic activity at concentrations as low as 10^{-6} M (Massaad and Barouki 1999; Ramamoorthy *et al.* 1997; Soto *et al.* 1995). Whether the toxicity endpoints observed during chronic toxicity studies reported in this chapter are a result of endocrine disruption is not known. However, it is clear that organisms treated with endosulfan did exhibit some toxic effects that have historically been associated with endocrine disrupting chemicals, *e.g*., developmental and reproductive effects (Ankley *et al.* 1998).

EPA is required under Federal Food, Drug, and Cosmetic Act (FFDCA), as amended by the Food Quality Protection Act, to develop a screening program to determine whether certain substances (including all pesticide active and other ingredients) "may have an effect in humans that is similar to an effect produced by a naturally-occurring estrogen, or other such endocrine effects as the Administrator may designate." Following the recommendations of its Endocrine Disrupting Screening and Testing Advisory Committee (EDSTAC), EPA determined that there was scientific basis for including, as part of the program, the androgen- and thyroid-hormone systems, in addition to the estrogen-hormone system. EPA also adopted EDSTAC's recommendation that the Agency include evaluations of potential effects in wildlife. For pesticidal chemicals, EPA will use FIFRA and, to the extent that effects in wildlife may help determine whether a substance may have an effect in humans, FFDCA authority to require the wildlife evaluations. As the science develops and resources allow, screening of additional hormone systems may be added to the Endocrine Disruptor Screening Program (EDSP).

Endosulfan has demonstrated both reproductive and developmental effects in a broad range of organisms and has been implicated in peer-reviewed literature as an endocrine disrupting agent. Based on the chronic effects of endosulfan and open literature, EFED recommends that when appropriate screening and/or testing protocols being considered under the Agency's EDSP have been developed, endosulfan be subjected to more definitive testing to better characterize effects related to its endocrine disruptor activity.

Endangered Species

In 1989 the U.S. Fish and Wildlife Service (USFWS) issued a biological opinion (USFWS 1989) on endosulfan in response to the U. S. Environmental Protection Agency's request for consultation. In issuing its opinion the USFWS considered the following factors: (1) potential for exposure of the listed species to the pesticide; (2) information on the chemical toxicity relative to estimated environmental concentrations; (3) potential for secondary impacts; and (4) special concerns not specifically addressed in the preceding factors or unique to the situation being evaluated. Given the evaluation criteria, a total 130 species (6 amphibians, 77 fish, 32 mussels, 6 crustaceans, 4 miscellaneous aquatic invertebrates, and 5 bird species) were considered potentially affected by the use of endosulfan.   Of those organisms potentially affected, the USFWS listed 41 aquatic species as jeopardized, of which the majority (54%) were endangered/threatened species of freshwater mussels. Two terrestrial (avian) species were also classified as being in jeopardy. The remaining potentially affected organisms were listed either as having no potential for exposure or as not being in jeopardy. For all of the species listed as jeopardized the USFWS lists reasonable and prudent alternatives (RPA) to mitigate the effects of endosulfan use. For some of the species listed as not jeopardized, the USFWS lists reasonable and prudent measures (RPM) and incidental take (IT) to mitigate effects. For details on the RPA and RPM recommendations, the reader is referred to USFWS 1989 publication. Many additional species, especially aquatic species, have been federally listed as endangered/threatened since the biological opinion of 1989 was written, and determination of jeopardy to these species has not been assessed for endosulfan.   In addition, endangered insects were not considered in the 1989 opinion and need to be addressed. Finally, not only are more refined methods to define ecological risks of pesticides being used but also new data, such as that for spray drift, are now available that were not existent in 1989. The RPAs and RPMs in the 1989 biological opinion may need to be reassesed and modified based on these new approaches. This can occur once the program is finalized and in place.

At the current application rates, endosulfan use is likely to result in both acute and chronic risks to endangered/threatened species of animals.   The Agency does not currently have data on which to evaluate the toxicity of endosulfan to terrestrial and aquatic plants; thus, the risk to threatened/endangered plants is unknown. However, incident data suggest that under certain conditions endosulfan is phytotoxic. The Agency has developed the Endangered Species Protection Program to identify pesticides whose use may cause adverse impacts on endangered and threatened species, and to implement mitigation measures that will eliminate the adverse impacts. At present, the program is being implemented on an interim basis as described in a Federal Register notice (54 FR 27984-28008, July 3, 1989), and is providing information to pesticide users to help them protect these species on a voluntary basis. As currently planned, the final program will call for label modifications referring to required limitations on pesticide uses, typically as depicted in county-specific bulletins or by other site-specific mechanisms as specified by state partners. A final program, which may be altered from the interim program, will be described in a future Federal Register notice. The Agency is not imposing label modifications at this time through the RED. Rather, any requirements for product use modifications will occur in the future under the Endangered Species Protection Program.

Endosulfan as a PBT (Persistent, Bioaccumulative, and Toxic) Pollutant

The Agency proposed endosulfan as a candidate for the development of National Action Plans under the PBT Initiative. Various parameters were used for the initial selection process of PBT

candidates. They included among others, the relative hazard, the presence in the environment, and production volume.

Based on environmental fate laboratory studies, terrestrial field dissipation studies, available models, monitoring studies, and published literature, it can be concluded that endosulfan is a **very persistent** chemical which may stay in the environment for lengthy periods of time, particularly in acid media. Endosulfan may be transported via dissolution in water/via runoff, adsorption to soil particles/via erosion, vaporization and/or adsorption to dust particles/transport in the air. It is acknowledged, however, that endosulfan is not *as persistent as* some other chemicals previously or traditionally labeled as PBT's, such as DDT and various other chemicals.

Endosulfan is also **highly toxic** to nontarget aquatic and terrestrial animals. As indicated elsewhere in this report, its use has resulted in numerous incident reports. The vast majority of such incidents were associated with fish kills.

Based on the available data, it appears that endosulfan is not likely to be strongly bioaccumulative. On one hand, there is the fact that the chemical has a relatively high octanol/water partition coefficient (K_{OW}= 55500-61400) and bioaccumulation factors (2429X for edible tissue). On the other hand, one study presented a depuration half-life of 33 hours, and another study indicated that residues are likely to be endosulfan-sulfate. Furthermore, in a farm pond runoff study ˝ - and ˘ - endosulfan were not present in fish samples collected, only the endosulfan-sulfate was detected. The fact that endosulfan depurates rapidly from fish hinders further bioaccumulation in the food web. The Agency has requested a new Bioaccumulation in Fish study because the above mentioned studies do not follow current guidelines. The new study will clarify the actual extent of bioaccumulation and the rate of depuration of endosulfan and/or its transformation products in fish.

Despite the fact that endosulfan does not show all the three characteristics of a PBT compound, considerations of its properties of high persistence and toxicity should be addressed, and measurements of precaution taken at the time of Reregistration of the chemical.

REFINED RISK ASSESSMENT AND CHARACTERIZATION

From the preliminary risk assessment and characterization (see previous section), it is clear that endosulfan is persistent and prevalent in the environment and that endosulfan use may result in mortality to nontarget organisms, especially in aquatic systems. Unlike most preliminary (Tier 2) assessments, the assessment EFED used included several non-conservative assumptions, including the use of "typical" application rates, the exclusion of spray drift, and the exclusion of any additional toxicity effects of the degradate endosulfan sulfate. Even with these nonconservative assumptions, the Tier II results showed that important detrimental environmental effects would occur. In order to better characterize the extent and magnitude of the risk posed to nontarget aquatic organisms by the use of endosulfan and to put the risk into context with the overall pattern of use of endosulfan, EFED considered a refined assessment aimed at answering the following four questions:

(1)   What is the maximum application rate that would not trigger a level of concern (specifically the acute high risk LOC) on nontarget aquatic species?

(2)   What is the probability that the current actual use patterns will cause exceedance of LOCs?

(3)   What are the probability and extent of detrimental aquatic effects?

(4)   How do the modeled environmental concentrations used in the risk assessment compare to the overall range of expected concentrations of endosulfan in use areas?

The refined assessment focuses on acute risks to aquatic organisms which, based on the preliminary assessment, are the nontarget organisms that are at greatest risk from the use of endosulfan. Incident data already illustrate the acute impacts of endosulfan on fish. This does not mean that risks do not exist for nontarget terrestrial organisms–and indeed the assessment does predict exceedances of acute and chronic levels of concern–but that the risks are greatest for aquatic organisms. While some studies suggest amphibian impacts, the extent of available literature present conflicting results that will be difficult to support.

Application Rates that Will Not Exceed the Level of Concern

EFED determined the maximum single application rates which could be applied such that acute high risk levels of concern (LOC) for freshwater fish would not be exceeded. For this analysis, the acute LC_{50} for bluegill sunfish (of 1.7 . g/L) and striped bass (0.1 . g/L) were used as target aquatic concentrations, and the corresponding application rate was back calculated using PRZM/EXAMS. Table 16 shows the maximum application rates that could be used so as not to exceed the LOC. Note that these maximum rates consider only a single application; with multiple applications, as allowed on the endosulfan label, the allowable maximums would be even lower. With the exceptions of the apple scenario (with sunfish), the ecologically desirable application rates are much lower than the endosulfan labels allow.

Table 16. Maximum application rates (lbs. a.i./A) beyond which acute high risk level of concern (LOC ˘ 0.5) is exceeded for bluegill sunfish (LC_{50} = 1.7 . g/L) and stripped bass (LC_{50} = 0.1 . g/L).

Crop	Bluegill Sunfish (lbs. a.i./A)	Stripped Bass (lbs. a.i./A)	Labeled Single Application Rate (lb/A)
Apples	4.82	0.28	1.5
Cotton	0.39	0.02	1.5
Lettuce	0.76	0.04	1.5
Pecans	0.12	0.007	1.5
Potatoes	0.57	0.03	1
Tomatoes	0.15	0.009	1

Probability of a Typical Single Application Exceeding the LOC

Even typical application rates are much higher than the desirable application rate, as Figures 3a through 3g show. These figures compare the distribution of actual single application rates for endosulfan on modeled crops to the maximum application rate beyond which the acute high risk LOC would be

exceeded. This distribution is based on data collected in California and makes the assumption that a similar distribution of application rates holds for the rest of the endosulfan use areas. For 4 crops (tomatoes, pecans, cotton and potatoes) more than 90% of the typical single application rates would result in estimated environmental concentrations that exceed acute high risk LOCs for freshwater fish. Roughly 83% of the single application rates for lettuce are greater than the maximum application rate beyond which the acute high risk LOC is exceeded (0.76 lbs. a.i./A, based on bluegill sunfish LC_{50}). However, had the most sensitive fish species (*i.e.*, stripped bass), been used to estimate risk quotients, the maximum allowable application would be 0.04 lbs. a.i./A, and 99.9% of the current application rates would result in exceedance. In contrast, typical application rates for endosulfan on apples, which ranged from 0.5 to 2 lbs a.i./A and averaged 0.57 lbs. a.i./A, were all less than the estimated rate (4.5 lbs. a.i./A) that would exceed acute high risk LOCs for bluegill sunfish. However, similar to lettuce, if LOCs were based on the acute mortality estimate for stripped bass, the maximum allowable application rate would be 0.28 lbs. a.i./A and roughly 90% of the typical application rates would exceed acute high risk LOCs.

Figure 3 depicts single application rates and shows that four out of the six crops modeled are likely to exceed acute high risk LOCs for freshwater fish. A comparison of typical single application rates to typical seasonal application rates (Table 17) indicates that, except for potatoes, seasonal application rates are generally higher. On the two crops where exceedance of acute high risk LOCs were less likely based on single application rates, *i.e.*, lettuce and apples, the seasonal rates were roughly 1.5 and 3.2 times the single application rates for lettuce and apples, respectively. Thus, on a seasonal basis, estimated environmental concentrations are likely to exceed acute high risk LOCs for lettuce; whereas for apples, the seasonal rate remains below the projected limit of 4.8 lbs. a.i./A.

Table 17. **Mean typical single and seasonal application rates and range of typical single and seasonal application rates for endosulfan by treatment site in California. Reported values based on 1998 California Department of Pesticide Regulation's (DPR) Pesticide Use Reporting (PUR) data.**

Crop	Mean Typical Application Rate (lbs. a.i./A)	Typical Application Rate Range (lbs a.i./A)	Mean Seasonal Application Rate (lbs a.i./A)	Seasonal Application Rate Range (lbs a.i./A)
Apples	0.57	0.5 - 2.0	1.85	0.5 - 3.7
Cotton	0.84	0.2 - 1.65	0.93	0.30 - 2.22
Lettuce	0.90	0.03 - 2.0	1.31	0.15 - 4.40
Pecans	1.31	0.5 - 2.21	1.55	0.5 - 4.01
Potatoes	0.85	0.75 - 0.94	0.85	0.75 - 0.94
Tomatoes	0.87	0.24 - 5.42	1.22	0.56 - 12.73

Figure 3: Frequency of single application rates (lbs a.i./Acre) for endosulfan use on modeled crops in California. Red arrow indicates maximum predicted application rate beyond which acute high risk level of concern (LC_{50}/EEC ˇ 0.5) for freshwater fish is exceeded. (Application rates provide by BEAD using California pesticide use reporting system).
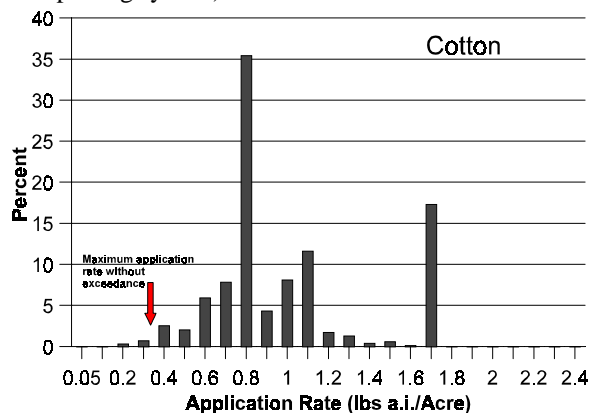
Figure 3a. Cotton
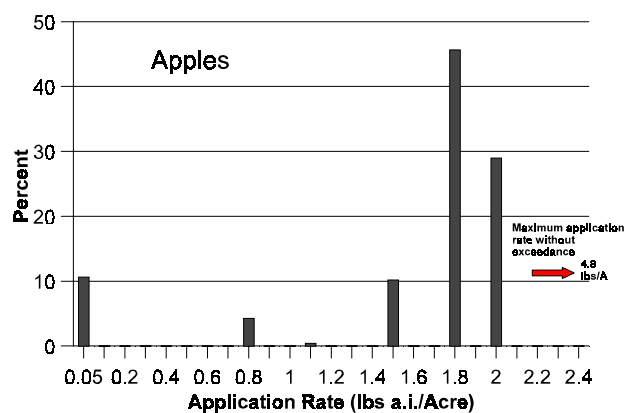
Figure 3b. Apples
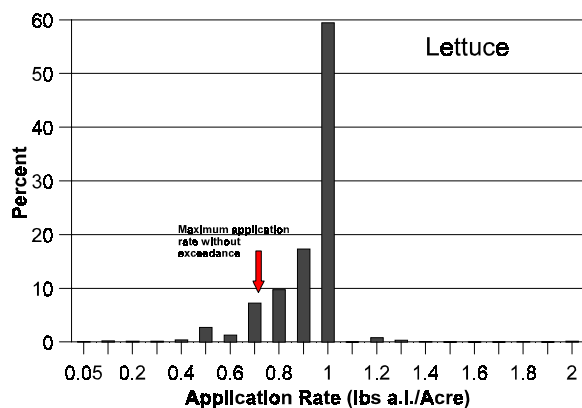
Figure 3c. Lettuce
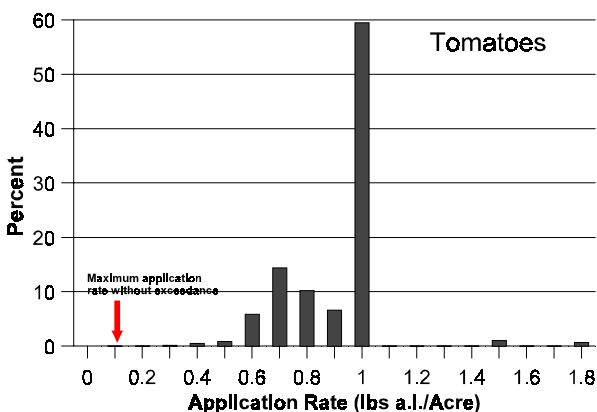
Figure 3d. Tomatoes
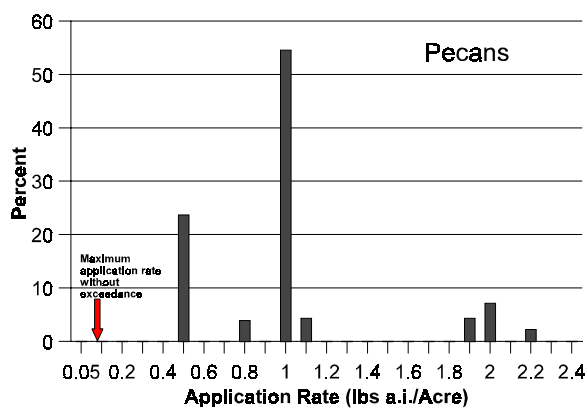
Figure 3f. Pecans.
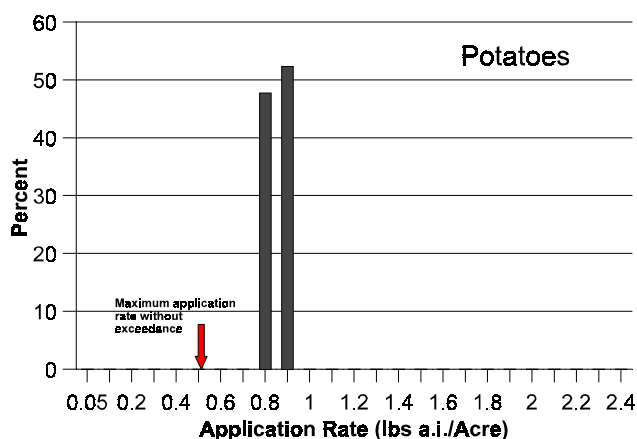
Figure 3e. Potatoes.

Probability and Extent of Detrimental Aquatic Impacts

This phase of the refined assessment considers the probability of endosulfan affecting an aquatic system as a whole. A complete description of the method is given in Appendix I, and only a brief description will be given here. The methods used in this assessment and other probabilistic methods are currently under development in EFED, and thus this assessment is not definitive and further refinements in the techniques used should be expected. However, this assessment does provide some important insight into the expected effects of endosulfan on whole aquatic ecosystems.

In this analysis, ten species for which acute toxicity effects are available are assumed to represent the distribution or "universe" of all aquatic species. This assumed universe comprised striped bass, pinfish, rainbow trout, flathead catfish, channel catfish, flathead minnow, bluegill sunfish, eastern oysters, blue crab, and fiddler crab. The LC_{50}s for these species ranged from 0.1 ppb for striped bass to 790 ppb for fiddler crab. The LC_{50} distribution of effects data were then compared to the distribution of 96-hr exposure data generated using PRZM/EXAMS with typical application rates. Exposure distributions were based on 96-hr values since effects data were primarily 96-hr studies. In this way, the probability of species mortality and the magnitude of the effect (percent of species affected) could be determined.

This concept is presented in Figure 4 which depicts the fraction of species affected by the likelihood of exceeding an EEC for all eight crop scenarios. The probability of exceeding an EEC during any given year is shown on the X-axis for each of the modeled crops. The Y-axis shows the fraction of species (in this modeled aquatic universe) that will be adversely affected by the EEC. Clearly, a wide range of effects is likely to occur. On the least vulnerable crop (*i.e.*, apples) endosulfan use is expected to minimally result in a nontarget aquatic mortality (50% mortality rate) 10% of the time affecting 10% of the aquatic organisms. However, on more vulnerable crops (*e.g.,* tomatoes) more than 90% of the time roughly 60% of the aquatic species will express a 50% mortality rate. Even with the nonconservative methods used in this analysis, it is apparent from the above graph that there is a very strong likelihood that detrimental ecological effects will occur during any given year.
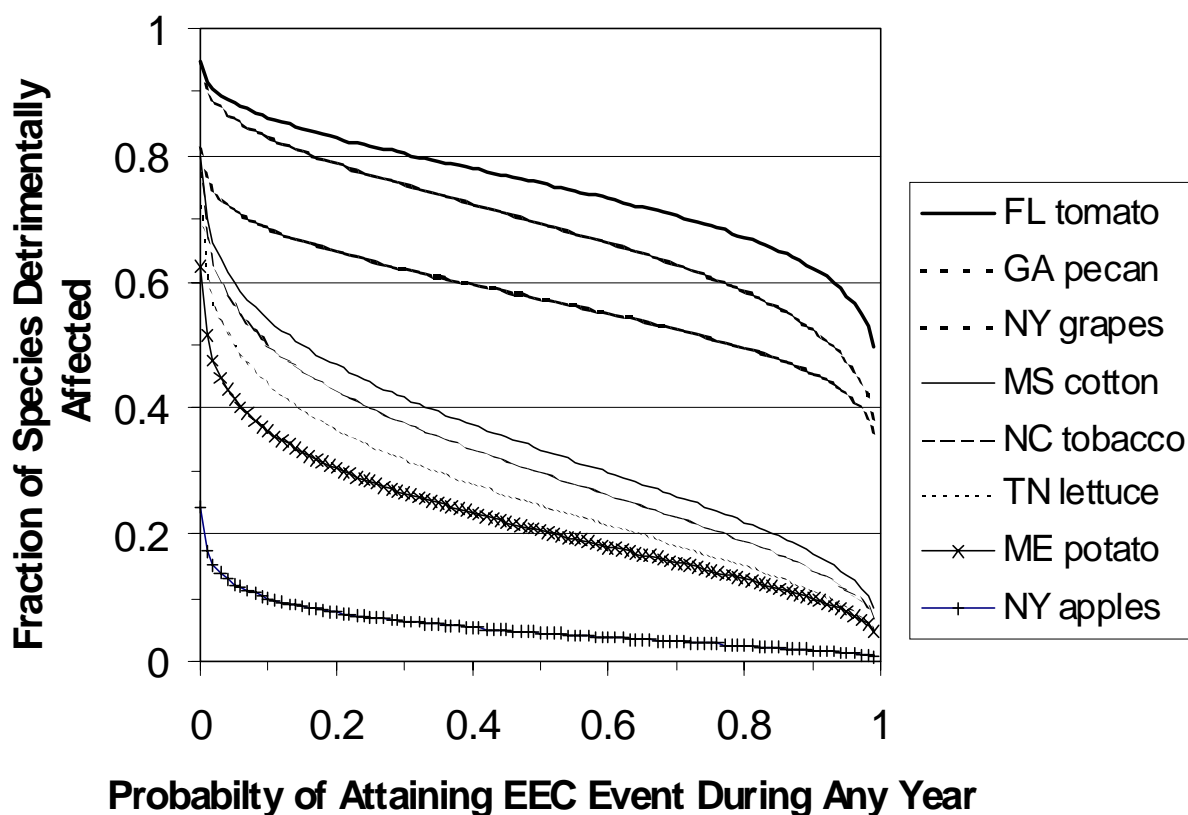
Figure 4. Extent of detrimental effects as a function of the likelihood of attaining an EEC. The x-axis represents the probability of attaining an EEC during any year, and the y-axis represents the fraction of species that will be detrimentally affected at that EEC.

Comparison of Modeled Endosulfan Concentrations to Monitoring

While few national water monitoring studies have included endosulfan, the STORET database contains extensive records of ″- and ˇ-endosulfan and endosulfan sulfate detections in water. The STORET data are not reliable enough to enable an accurate quantitative assessment of the endosulfan in water, although the records indicate a widespread distribution of endosulfan residues within the use areas of the pesticide. A comparison of the distribution of endosulfan detects reported in STORET with estimated environmental concentrations (EECs) of endosulfan from PRZM/EXAMS modeling indicates that the EECs are within the realm of potential concentrations measured in surface waters. It is important to note that the STORET data are highly unlikely to have captured peak concentrations and are more likely to represent longer-term mean concentrations. Even so, in some instances the high-end tails of the monitoring data (up to 1 ppm) are greater than yearly peak concentrations from PRZM/EXAMS runs. A Monte Carlo simulation of STORET data (Figure 5) generated a distribution with the following statistics (actual values in parenthesis): mean concentration, 137 ppt (166 ppt), with a standard deviation of 379 ppt (975 ppt); maximum value of 6,942 ppt (1 ppm) and minimum value of 0.13 ppt (0.1 ppt). Compared to the LC_{50} value for one of the most sensitive freshwater species, *i.e.*, rainbow trout LC_{50} of 800 ppt, the

maximum value from the STORET distribution exceeds the LC_{50} value by a factor of 8.7 and, as such, exceeds EFED's acute high risk level of concern. Additionally, based on the dose-response curve, the upper 10th percentile and 50th percentile values will likely result in the death of 12% and 10%, respectively, of fish with sensitivity similar to that of rainbow trout.

Forecast: Distribution of Storet data

2,000 Trials   **Frequency Chart**   **43 Outliers**
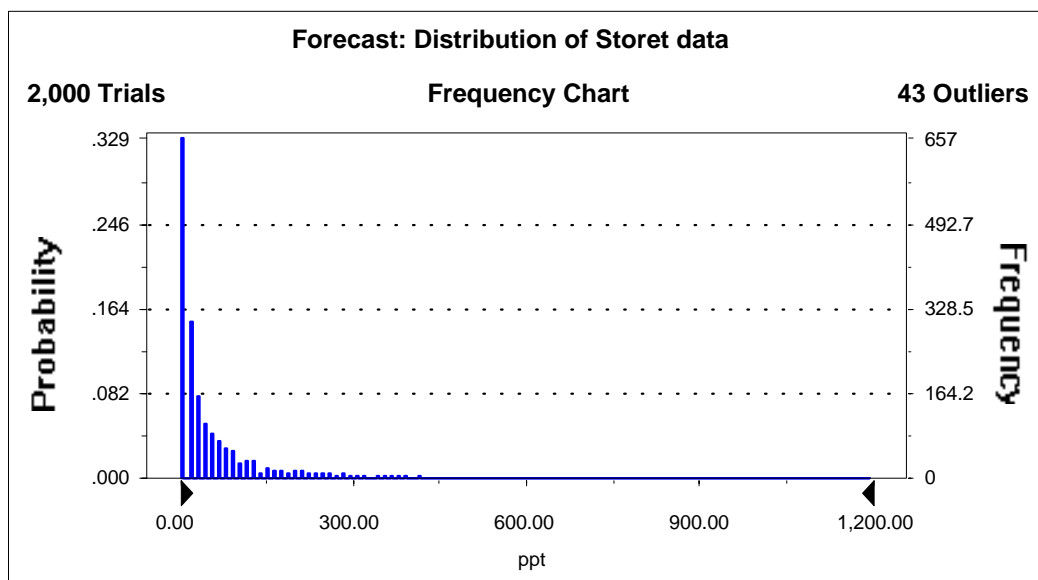
Figure 5: Distribution of STORET monitoring data for total endosulfan residues.

Summary and Conclusion

EFED used probabilistic assessment techniques to conduct a more refined risk assessment that was based on actual reported application rates in California coupled with a 300-ft spray-drift buffer. This assessment predicts that, for the least vulnerable crops (e.g., apples), the use of endosulfan at typical application rates has a 10% probability of resulting in mortality to 10% of the aquatic species in a given year. On more vulnerable crops (*e.g.,* tomatoes) the use of endosulfan at typical application rates in a given year resulted in a 90% probability that 60% of the aquatic species will be killed, a 50% probability that 75% of the species will be killed, and a 10% probability that 90% of the species will be killed. Based on the available toxicity data, incident data, and a refined risk assessment, endosulfan represents a high acute risk to aquatic organisms. Although EFED's screening level and refined risk assessments make assumptions about exposure and effects models, the assumptions for this assessment are not particularly conservative. EFED has focused primarily on aquatic risk; however, endosulfan is clearly a risk to terrestrial nontarget organisms as well. Additionally, the refined risk assessment addresses the probability and magnitude of acute effects. However, adverse chronic impacts can be expected given that chronic risk quotients are several orders of magnitude greater than acute values and given endosulfan's capacity to act as an endocrine disruptor and its persistence in the environment.

REFERENCES

This section includes citations for those references which do not have assigned MRID or

Accession numbers. Appendix C includes a complete list of references reviewed as a part of the assessment of published scientific literature on endosulfan, primarily focusing on the fate and transport of endosulfan. Appendix E includes a complete list of ecological toxicity references submitted to the Agency. That reference list also indicates whether the submitted study provided acceptable (met guideline requirements), supplemental (did not meet guideline requirements but still provided some useful information), or unacceptable (met neither guideline requirements nor provided useful information) data for use in the ecological effects assessment.

Ankley, G.E. Mihaich, R. Stahl, D. Tillitt, T. Colborn, S. McMaster, R. Miller, J. Bantle, P. Campbell, N. Denslow, R. Dickerson, L. Folmar, M. Fry, J. Giesy, L.E. Gray, P. Guiney, T. Hutchinson, S. Kennedy, V. Kramer, G. LeBlanc, M. Mayes, A. Nimrod, R. Patino, R. Peterson, R. Purdy, R. Ringer, P. Thomas, L. Touart, G. Van der Kraak, and T. Zacharewski. 1998. Overview of a workshop on screening methods for detecting potential (anti-) estrogenic/androgenic chemicals in wildlife. Environmental Toxicology and Chemistry 17(1): 68 - 87.

Barry, M.J., and D.C. Logan. 1998. The use of temporary pond microcosms for aquatic toxicity testing: direct and indirect effects of endosulfan on community structure. Aquatic Tox. 41:101-124.

Berrill, M., D. Coulson, L. McGillivray, and P. Pauli 1998. Toxicity of endosulfan to aquatic stages of anuran amphibians, Environmental Toxicology and Chemistry 17 (9): 1738 - 1744.

Braunbeck, T. and S. Appelbaum. 1999. Ultrastructural alterations in the liver and intestine of carp *Cyprinus carpio* induced orally by ultra-low doses of endosulfan. Dis. Aquatic Organ. 36(3): 183 - 200.

Cotham, W.E. and T.F. Bidleman. 1989. Degradation of malathion, endosulfan, and fenvalerate in seawater and seawater/sediment microcosms. J. Agric. Food Chem. 37: 824-828.

Ecobichon, D. J. 1991. Toxic effects of pesticides. In M. O. Amdur, J. Doull and C. Kaassen eds., Toxicology The Basic Science of Poisons. Pergamon Press., New York. Pages 65 - 622.

Edwards, J.A., et al, 1984. Effect of Endosulfan-Technical (Code 02671 0 I AT209) on Reproductive Function in the Rat. Hoechst Aktien-gesellschaft. Huntingdon Research Centre, Study#: HST204/83768. July 19, 1984. HED Doc# 004881, 008868, 009552; TOX. CHEM.#: 420; ACC#: 256127; 41799301; TRID#: 460002-031; MRID#: 00148264.

Frank, R. and H. Braun. 1977. Organochlorine insecticides and industrial pollutants in milk supply of southern Ontario. Journal of Food Protection 42: 31 - 37.

Gillesby, B.E. and T.R. Zacharewski. 1998. Exoestrogens: mechanisms of action and strategies for identification and assessment. Environmental Toxicology and Chemistry 17 (1): 3 - 14.

Gorlitz, G. 1988a. Endosulfan (HOE 002671) adsorption/desorption in the system soil/water, part I: HOE 052618 (= ˝ -endosulfan) HOE 052619 (=ˇ -endosulfan). Hoechst Aktiengesellschaft, Germany. Unpublished study. Document No A37591. March 2, 1988.

Gorlitz, G. 1988b. Endosulfan (HOE 002671) adsorption/desorption in the system soil/water, part II:

HOE 051327 (= endosulfan-sulfate) HOE 051329 (= endosulfan-diol). Hoechst Aktiengesellschaft, Germany. Unpublished study. Document No A39353. September 23, 1988.

Guerin, T.F., and I.R. Kennedy. 1992. Distribution of endosulfan and related cyclodienes in sterile aqueous systems: Implications for studies on biodegradation. J. Agric. Food Chem. 40:2315-2323.

Gupta, P. K. and R. C. Gupta. 1979. Pharmacology, toxicology and degradation of endosulfan. A review. Toxicology 13: 115 - 130.

Halsall, C.J., R. Bailey, G.A. STern, L.A. Barre, P. Fellin, D.C.G. Muir, B. Rosenberg, F.Y. Robinsky, E.Y. Kononov, and B. Pastukhov. 1998. Multi-year observations of organohalogen pesticides in the Artic atmosphere. Environ. Pollution 102:51-62.

Heufelder, A. and L.C. Hofbauer. 1996. Environmental endocrinology: hidden, but potent ways of activating the estrogen receptor. European Journal of Endocrinology 135: 653 - 655.

Lehotay, S.J., J.A. Harman-Fetcho, and L.L. McConnell. 1998. Agricultural pesticide residues in oysters and water from two Chesapeake Bay tributaries. Marine Pollution Bull. 37(1-2):32-44.

Leys, F. F., F. J. Larney, J. F. Müller, M. R. Raupach, G. H. McTainsh and A. W. Lynch. 1998. Anthropogenic dust and endosulfan emissions on a cotton fram in northern New South Wales, Australia. The Science of the Total Environment 220: 55 - 70.

Lutz., H. and Y. Lutz-Ostertag. 1975. Intersexuality of the genital system and "Free-Martinism" in birds. In, R. Reinboth, editor, Symposium on Intersexuality in the Animal Kingdom. Springer-Verlag, New York: 382 - 391.

Maier-bode, H. 1968. Properties, effect, residue and analytics of the insecticide endosulfan. Residue Reviews Vol 22: 1 - 43.

Massaad, C., and R. Barouki. 1999. An assay for the detection of xenoestrogens based on a promoter containing overlapping EREs. Environmental Health Perspectives 107, No. 7.: 563 - 566.

McConnell, L.L., J.S. Lenoir, S. Datta, and J.N. Seiber. 1998. Wet deposition of current-use pesticides in the Sierra Nevada Mountain Range, California, USA. Environ. Toxicol. Chem. 17(10): 1908-1916.

Montgomery, J.H. 1993. Agrochemicals desk reference. Environmental data. Lewis Publishers, Chelsea, MI.

Pait, A. S., A. E. DeSouza, and D. R. G. Farrow. 1992. Agricultural pesticide use in coastal areas: a national summary. U.S. Department of Commerce, National Oceanic and Atmospheric Administration.

Paul, V. and E. Balasubramaniam. 1997. Effects of single and repeated administration of endosulfan on behaviour and its interaction with centrally acting drugs in experimental animals: a mini review. Environmental Toxicology and Pharmacology 3: 151 - 157.

Ramamoorthy, K., F. Wang, I. Chen, J. D. Norris, D. P. McDonannell L. S. Leonard, K. W. Gaido, Wl P. Bocchinfuso, K. S. Korach, and S. Safe. 1997. Estrogenic activity of a dieldrin/toxaphene misture in mouse uterus, MCF-7 human breast cancer cells, and yeast-based estrogen receptor assays: no apparent synergism. Endocrinology Vol. 138, No. 4: 1520 - 1527.

Rauh J. J., E. Benner, M. E. Schnee, D. C.ordova, C. W. Holyoke, M. H. Howard, D. Bai, S. D. Buckingham, M. L. Hutton, A. Hamon, R. T. Roush, and D.B. Sattelle. 1997. Effects of [^{3}H]-BIDN, a novel bicyclic dinitrile radioligand for GABA-gated chloride channels of insects and vertebrates. British Journal of Pharmacology 121 (7): 1496 - 1505.

Reno, F.E., 1975. Acute Oral Toxicity Study in Rats: Project No. 915-108 (Unpublished study received July 28, 1980 under 2749-487; prepared by Hazelton Lab. America Inc. Submitted by Aceto Chemical Co., Inc., Flushing, N.Y. CDL:243082-A). MRID#:00038307

Rice, C.P., S.M. Chernyak, C.J. Hapeman, and S. Bilboulian. 1997a. Air-Water distribution of the Endosulfan Isomers. J. Environ. Qual. 26(4): 1101-1106.

Rice, C.P., S.M. Chernya, and L.L. McConnell. 1997b. Henry's Law constants for pesticides measured as a function of temperature and salinity. J. Agric. Food Chem. 45:2291-2298.

Rosa, S., E. F. Rodriguez and C. Sanfeliu. 1996. Cytotoxicity of hexachlorocyclohexane isomers and cyclodienes in primary cultures of cerebellar granule cells. J. Pharmacol. Exp. Ther. 278: 163.

Schmidt, W.F. C.J. Hapeman, J.C. Fettinger, C.P. Rice, and S. Bilboulian. 1997. Structure and Asymmetry in the Isomeric Conversion of ˘ - to ˝ -Endosulfan. J. Agric. Food Chem. 45(4): 1023-1026.

Singh, N.C., T.P. Dasgupta, E.V. Roberts, and A. Mansingh. 1991. Dynamics of Pesticides in Tropical Conditions. 1. Kinetic Studies of Volatilization, Hydrolysis, and Photolysis of Dieldrin and ˝ - and ˘ - Endosulfan. J. Agric. Food Chem. 39: 575-579.

Soto, A. M., C. Sonnenschein, K. L. Chung, M. F. Fernandez, N. Olea, and F. O. Serrano. 1995. The E-SCREEN assay as a tool to identify estrogens: an update on estrogenic environmental pollutants. Environ. Health Perspect 103 (Suppl 7): 113 -- 122.

Soto, A. M., K. L. Chung, and C. Sonnenschein. 1994. The pesticides endosulfan, toxaphene, and dieldrin have estrogenic effects on human estrogen-sensitive cells. Environmental Health Perspectives 102(4):

Sylianco, C. Y. L. 1978. Some interactions affecting the mutagenicity potential of dipyrone, hexachloraphene, thiodan and malathion. Mutation Research 53: 271 - 272.

U.S. EPA OPP. 1992. Pesticides in Ground Water Database. A Compilation of Monitoring Studies : 1971-1991. National Summary. EPA/OPPTS, EA 731-12-92-001, Sept. 1992.

U.S. EPA. 1994. Ecological Incident Information System. EPA 734-K-94-001.

U.S. EPA. 1997. The Incidence and Severity of Sediment Contamination in Surface Waters of the United States. 3 volumes. EPA 823-R-97-006, -007, -008. Sept. 1997.

U.S.F.W.S. 1989. Final Biological Opinion in Response to U. S. Envrionmental Protection Agency's September 30, 1988, Request for Consultation on Their Pesticide Labeling Program. U. S. Department of Interior, Fish and Wildlife Servide (EHC/BFA?9-89-1).

U.S. F.W.S 1996. Final Biological Opinion: Effects of 15 chemicals on threatened and endangered species. Part II Volume 2

Usha Rani, M. V., O. S. Reddi, and P. P. Teddy 1980. Mutagenicity studies involving aldrin, endosulfan, dimethoate, phophamidon, carbaryl and ceresan. Environ. Contam. Toxicol. 25: 277 - 282.

Velazquez, A., A. Creus, N. Xamena, and R. Marcos. 1984. Mutagenicity of the insecticide endosulfan in *Drosophila melanogaster*. Mutation Research 136: 115 - 118.

Wade, T. L., J. L. Sericano, P. R. Gardinali, G. Wolff, and L. Chambers. 1998. NOAA's "mussel watch" project: current use organic compounds in bivalves. Marine Pollution Bulletin, Vol 37, No. 1 -2: 20 - 26.

Willis, G. H. and L. L. McDowell. 1987. Pesticide persistence on foliage. Reviews of Environmental Contamination and Toxicology, Vol 100: 23 - 73.

Wilson, V. S. and G. A. LeBlanc. 1997. Endosulfan elevates testosterone biotransformation and clearance in CD-1 mice. Toxicology and Applied Pharmacology 148: 158 - 168.

Zou, E., M. Fingerman. 1997. Synthetic estrogenic agents do not interfere with sex differentiation but do inhibit molting of the Cladoceran *Daphnia magna*. Bulletin of Environmental Contamination and Toxicology 58: 596 - 602.

The following studies submitted by the registrant met the appropriate guideline requirements or provided ancillary information on the fate of endosulfan in the environment.

Chemical Degradation

161-1 Hydrolysis

˝- and ˘-isomers of endosulfan were stable in sterile aqueous pH 5 buffer solutions. The same isomers degraded with a half-life of 11-19 days in pH 7 sterile aqueous buffered solutions. In the pH 9 aqueous buffer solutions, the recovery was ˛84% starting from 21 days (approximately 70 times the half-life of 4-6 hours). All samples were incubated in the dark at 25±1°C for 30 days. Endosulfan-sulfate was not detected in any of the samples. The major degradation product was endosulfan-diol, which peaked at 58-74% of applied at 30 days for the pH 7 solution, and 90-92% of applied at 1 day for the pH 9 solutions, decreasing very slowly to 68-69% at 30 days (MRID 414129-01).

Table A-1: Hydrolysis half-lives for endosulfan (MRID 414129-01).

pH	˝-endosulfan	˘-endosulfan	Degradates (Maximum % of applied)
5	> 200 da (stable)	> 200 da (stable)	
7	19 da	11 da	endosulfan-diol (58-74% at 30 days)
9	0.3 da (6 hr)	0.2 da (4 hr)	endosulfan-diol (90-92% at 1 day)

161-2 Photodegradation in Water

A study reviewed in 1993 (MRID 414157-01) was considered <u>unacceptable</u> because the samples were irradiated with a mercury vapor lamp, which does not reflect natural sunlight. However, supplemental information from the UV spectra provided by the registrant suggest that aqueous photolysis is not an important route of dissipation/degradation for ˝- or ˘-endosulfan. The absorbance spectra submitted by the registrant for ˝- and ˘-endosulfan, endosulfan sulfate, and endosulfan diol show no significant absorbance in the 290-800 nm range.

161-3 Photodegradation on Soil

Endosulfan (2:1 ˝:˘ isomer ratio) was stable to photolysis on a pH 6.4 silt loam soil irradiated for 30 days with natural sunlight. At the end of the 30-day study, the amount of endosulfan remaining in the irradiated samples – 58-59% of ˝-endosulfan and 33-34% of ˘-endosulfan – was similar to that remaining in the dark controls – 60-62% and 34%, respectively. endosulfan-diol was detected in both irradiated and dark control samples at a maximum of 3-5% after 30 days (MRID 414307-01).

161-4 Photodegradation in Air

This study has been waived because absorbance spectra showed no significant absorbance in the 290-800 nm range for the parent or major degradates and because the low vapor pressures of the parent

isomers and degradates are moderate.

Metabolism

162-1 Aerobic Soil Metabolism

A study conducted in accordance with the German BBA Guideline IV, 4-1 (MRID 438128-01) provides supplemental information on the aerobic soil metabolism of alpha- and beta- endosulfan. The registrant reports DT_{50}'s calculated using a linear regression similar to that used to calculate $t_{1/2}$'s. Apparently only a limited number of points were used in this calculation. In this way, the reported "$t_{1/2}$'s" are more like DT_{50}'s (50% disappearance times). EFED recalculated the $t_{1/2}$ values with all the data provided in the study. A summary of the values obtained are as follows:

Table A-2: Aerobic Soil Metabolism Half-lifes and Disappearance Times for Alpha- and Beta-Endosulfan and Endosulfan Sulfate (MRID 438128-01).

Soil		SLV: sandy loam, Germany	LS2.2: loamy sand, Germany	SL2: silt loam, Mississippi	F821: sandy loam, Germany	SLG: sandy loam, Georgia
pH ($CaCl_2$)		5.5	5.0	5.6	7.1	5.8
Clay/Sand, %		9.5/58.6	5.7/85.4	18.1/15.3	12.4/61.0	10.0/>79.6
Organic C, %		0.95	2.9	0.7	2.3	2.4
˝-Endo-sulfan	$t_{1/2}$[1], da	40	61	35	67	40
	DT_{50}, da	12	39	79	<10	14
	DT_{90}, da	39	128	262	<30	46
˘-endo-sulfan	$t_{1/2}$, da	215	265	125	104	108
	DT_{50}, da	158	264	132	108	115
	DT_{90}, da	523	877	440	357	383
Ttl endo-sulfan	$t_{1/2}$, da	125	124	83	86	75
	DT_{50}, da	98	128	90	92	80
	DT_{90}, da	326	426	299	305	265
Endo + SO_4[2]	$t_{1/2}$, da	824	2148	392	288	337
	DT_{50}, da	614	2241	454	288	339
	DT_{90}, da	2038	7443	1510	958	1126

1 First order half-life ($t_{1/2}$) calculated by EPA reviewer; DT_{50} and DT_{90} values reported by registrant.
2 Half-life and disappearance times are calculated for the combined concentrations of endosulfan and endosulfan-sulfate, expressed on an endosulfan equivalent basis.

A mixture of [^{14}C]-˝- and ˘-endosulfan was applied at a nominal rate of 1.3 mg/kg (1.0 kg/ha) to the five study soils. The ˝-isomer dissipated more rapidly than the ˘-isomer, with half-lives of 35-67 days compared to 104-265 days. The major degradation product in all cases was endosulfan sulfate,

which increased in time to maximum levels of ˘ 52% of the applied. No clear pattern of decline could be estimated for endosulfan sulfate. The combined half-life of total endosulfan isomers and endosulfan-sulfate residues ranged from 288 to 2,148 days. The lactone- and diol- degradates of endosulfan were minor components (<10% of the applied). Non-extractable matter generally increased with time, to a maximum of 39% at 272 days for the SL2 soil. $^{14}CO_2$ reached almost 10% after 365 days in F821 and 6% in SLG, but was ˛ 2% in the other 3 soils. Other volatiles were ˛ 2% of the applied in all cases. Recoveries were generally >90% of the applied.

Several deficiencies limit the usefulness of the study:

> Inadequate sampling intervals reduce the certainty of the half-life determinations: Greater than 50% of ˝-endosulfan degraded between two consecutive sampling intervals in the three sandy loam and silt loam soils; greater than 50% of ˘-endosulfan degraded between 120 and 365 days (the next sampling interval) posttreatment.

> Reported material balances were not determined using valid means: Volatiles were not measured from the same system from which the residues were determined, precluding an accurate determination of material balances.

> Characteristics of the three foreign soils were not compared with domestic (US) soils in order to extrapolate results to US conditions. This is particularly critical for a pesticide such as endosulfan, which has a variety of uses.

> Parent and degradates were not confirmed with a second analytical method: Only HPLC was used to detect and quantify endosulfan isomers and degradation products. EPA requires a second analytical method (such as GC/MS or two-dimensional TLC) to confirm the HPLC assessment.

> Incubation temperature (21±2°C) may not have remained constant during the study, although no raw data was provided to determine the frequency and magnitude of fluctuations.

> The humidity of the soil was kept at 40% of the maximum water holding capacity. Generally studies are conducted at 75% of 1/3 bar.

Despite these problems, EFED believes the study is sufficient to characterize aerobic soil metabolism for endosulfan because results for the five soils were similar with consistent degradation patterns/profiles and reasonable correlation coefficients. A new study is not expected to provide substantial new information about the aerobic degradation of endosulfan. However, an aerobic soil metabolism study for the endosulfan-sulfate degradate may be needed to establish the degradation pattern of this compound.

A study (MRID 414129-02) screened in 1993 was found to be invalid. The study was conducted only for 60 days, and the pattern of formation and decline of the degradates could not be established. In addition, the study was conducted with a German soil. The following supplemental information could be extracted from the study:

> Endosulfan (a mixture of ˝- and ˘-isomers) degraded with a half-life of 37 days in a German

sandy loam soil incubated aerobically for 60 days. The degradation half-lives for the ˝ - and the ˇ -isomers were 23 and 58 days, respectively. The major degradate was endosulfan sulfate (34.7% of the applied at 30 days). Volatiles were not determined.

162-2 Anaerobic Soil Metabolism

In the study summarized in Table A-3, the treated samples were incubated aerobically for 24 days before being flooded with peptone-amended water for 64 days. The ˇ -endosulfan isomer degraded more slowly under anaerobic conditions than did the ˝ - isomer. Endosulfan-sulfate was the only degradate detected during the aerobic phase of the study, peaking at 35% in the German sandy loam (pH 7.2) and 19% in the MS silt loam (pH 6.4). During the anaerobic phase, endosulfan-sulfate decreased to 22% and 15%, respectively (MRID 414129-04), with a calculated half life of 120 days in the sandy loam soil and 165 days in the silt loam soil.

Table A-3: Anaerobic Soil Metabolism Half-lives for ˝-, ˇ-, and 2:1 Combined Endosulfan (MRID 414129-04)

Soil	pH	˝-endosulfan	ˇ-endosulfan	Combined isomers (2:1 ˝:ˇ)	Anaerobic Degradates
German sl	7.2	105 da	161 da	144 da	endo-diol 10% endo-lactone 6% OH-carbonic acid 3%
MS sil	6.4	124 da	136 da	154 da	endo-diol 2% endo-lactone 4% OH-carbonic acid 1%

162-3 Anaerobic Aquatic Metabolism
162-4 Aerobic Aquatic Metabolism

One aerobic aquatic metabolism study submitted (MRID 449178-01) the agency was conducted in neutral to alkaline waters and sediments that favor hydrolysis. In this study, Total (5a,9a)-[^{14}C] ˝ - and ˇ -Endosulfan, at ! 0.229 mg/kg, declined from river Main (System I) and gravel-pit (System II) aerobic aquatic systems kept at 22±2°C in the dark, with respective registrant-calculated half-lives of 4 and 8 days.

The registrant reported various half-lives and DT_{50}'s of interest:

Parameter	System I (river Main)	System II (gravel-pit)
$t_{1/2}$ (˝ + ˇ -endosulfan) [days]	4	8
DT_{50} (˝ + ˇ -endosulfan) [days]	12	10
DT_{50} (total endosulfan residues) [days]	21	18

In the System I (river Main), at time 0, both ˝ - and ˇ -endosulfan appear predominantly in the water by a ratio of about 3:1. Such a ratio is approximately reversed by day 1 posttreatment.

In both systems the major transformation products were endosulfan sulfate and endosulfan

carboxylic acid (maximum of 48.6% of the applied, replicate 1, system II; and 35.5% of the applied, replicate 1, system II; respectively). Other minor degradates identified were endosulfan lactone (̩ 2.5% of the applied), endosulfan diol (̩ 2.4% of the applied), and endosulfan ether (̩ 0.8% of the applied).

The cumulative recovered volatile radioactivity after 7 weeks posttreatment (sulfuric acid, ethylene glycol, and ethanolamine/methanol traps) was ̩ 2.56% of the applied in the two test systems.

This study does not fully satisfy the aerobic aquatic metabolism data requirement; however, it provides some supplemental information about the aerobic aquatic metabolism of ˝- and ˘-endosulfan. The information obtained corresponds well with the expected behaviour according to data obtained from the other submitted studies, and from the literature. The following deficiencies were found during the screening of the study.

The study was conducted with slightly basic to basic sediment and water, alkaline conditions which favor hydrolysis, making it difficult to discern the role of metabolism in degradation.

Extractions of the soil do not appear to be exhaustive.

The aerobicity of the system was not established.

Soils and water from Germany were used; no attempt was made to compare them to the soils and waters likely to be found in the use areas in the United States.

This study was revised (MRID# 44917801) to confirm that the sediment samples were indeed extracted three times with a mixture of acetonitrile and toluene (4:1 by volume). This information was not transparent in the body of the original study, but it was obtained from one of the figures. However, this revision is not sufficient to reverse the decision to reject the study because the study presented several other deficiencies.

Mobility

163-1 Leaching and Adsorption/Desorption

Mobility for Parent Endosulfan: In a supplemental batch equilibrium study (MRID 414129-06), ˝- and ˘-endosulfan were determined to be immobile in silt loam, "loamy sand," sandy loam (SLV), and sandy loam (SLG). Soil:CaCl$_2$ slurries containing ˝- and ˘-endosulfan (and 0.1% acetone to obtain aqueous phases with stable initial concentrations of test substance) were equilibrated for 16 hours at 22±1°C. Results are listed below.

Table A-4: Adsorption Parameters for Endosulfan From Batch Equilibrium Studies (MRID 414129-06).

Soil Properties			˝-Endosulfan				ˇ-Endosulfan			
Registrant's designation and source location	Soil Texture	% o.c.	Freundlich Parameters [a]		Avg. K_d [b] (ml/g)	K_{oc} [c] (ml/g)	Freundlich Parameters [a]		Avg. K_d [b] (ml/g)	K_{oc} [c] (ml/g)
			K_f [(ml/g)(mg/L)$^{1-N}$]	N			K_f [(ml/g)(mg/L)$^{1-N}$]	N		
SL2, Mississippi	silt loam	0.62	63	0.99	66	10700	74	0.99	77	12500
LS22, Germany	loamy sand	2.66	364	1.02	320	12000	324	0.96	428	16000
SLV, Germany	sandy loam	1.28	102	0.92	154	12000	178	0.98	196	15300
SLG, Georgia	sandy loam	2.45	523	1.19	185	7500	211	0.97	245	10000
					Mean K_{oc} = 10,600 ml/g Std. dev. =2100 ml/g				Mean K_{oc} = 13,500 ml/g Std. dev. =2600 ml/g	

[a] Freundlich parameters defined by $S = K_f C^N$, where S is sorbed phase concentration in mg/kg and C is aqueous concentration in mg/L.
[b] average K_d was determined by the mean of S/C for each batch study.
[c] K_{oc} was determined from % o.c. and average K_d.

The study is supplemental because the concentration ranges of ˝-endosulfan (0.02-0.13 mg/L) and ˇ-endosulfan (0.02-0.16 mg/L) in the soil:solution slurries were too narrow to calculate accurate Freundlich constants. EFED believes that Freundlich constants calculated with a narrow range of concentrations of analyte may provide inaccurate mobility information. The range should generally be at least 10-fold. The actual ranges were ! 5.5 fold for ˝-endosulfan, and ! 7-fold for ˇ-endosulfan. The K_{oc} values estimated in the registrant-submitted study are similar to or greater than (i.e., underestimates the degree of mobility) those found in the published scientific literature.

Mobility for Endosulfan Degradates: A batch equilibrium study for the sulfate and diol degradates of endosulfan (MRID 443469-01) is of questionable validity and can only be used to qualitatively identify the relative level of mobility of these degradates. This study is not acceptable and cannot be used to fulfill the US EPA data requirements due to several deficiencies:

Because preliminary study data indicated that the test compounds adsorbed to glass, conclusions concerning compounds mobility in soil were questionable.

Problems with adsorption of [^{14}C]endosulfan sulfate to glass prevented confirmation that the compound was completely soluble in the $CaCl_2$ solution at the highest treatment rate.

Additionally, the 3-hour equilibration period used in the [^{14}C]endosulfan diol study may have been inadequate to achieve an acceptable level of adsorption for use in determining adsorption coefficients.

A study conducted on German soils (MRID 414129-05) provides supplemental, qualitative information on the sorption potential of endosulfan sulfate and endosulfan diol. Because adsorption and desorption were measured at only one concentration, the results should not be used quantitatively. A comparison of the relative sorption coefficients from this study with that of the parent isomers on similar soils suggests that endosulfan sulfate will be similarly to slightly more mobile than the parent while endosulfan diol appears to be substantially more mobile than the parent isomers.

Based on batch equilibrium studies, endosulfan-sulfate, at nominal concentrations of 0.025-1.0 µg/mL, appears to be mobile to slightly mobile in sandy clay loam, sandy loam, sand, and clay loam soil:solution slurries. In batch equilibrium studies conducted on endosulfan-diol at similar nominal concentrations, the degradate appeared to be mobile to very mobile in clay loam, sandy loam, sandy clay loam, and sand soil:solution slurries. Adsorption of the test compounds to the glass test vessel precludes definitive or quantitative conclusions on their mobility.

163-2 Volatility -- Laboratory

A supplemental laboratory volatility study (MRID 400606-01) provides only qualitative information about the level of volatilization of ˝- and ˇ-endosulfan from a greenhouse growth mix at 25°C and 40°C. The reported vapor pressure of endosulfan at 25°C is 7.2×10^{-6} mm Hg for ˝-endosulfan and 3.0×10^{-6} mm Hg for ˇ-endosulfan. At 25°C, total endosulfan measured in the traps after 45 days, ranged from <LOD - 2% of the applied for samples submitted to various levels of air flow rate (20, 100, 200 mL/min) and humidity (0, 25, 75% of field moisture capacity).

Endosulfan, applied as Thiodan 3 EC (2:1, ˝:ˇ isomers) at approximately 0.9 mg/kg, volatilized at a maximum of 42.2 pg/cm^2/hr at approximately 52 hours from a greenhouse growth medium ("Jiffy Mix") adjusted to 75% of field moisture capacity and incubated at 40°C with an airflow rate of 100 mL/min. The maximum air concentration was 0.354 µg/m^3 at 22 hours and decreased to 0.070 µg/m^3 by 1079 hours posttreatment. Total endosulfan loss from the flask during the experiment was 5.5%. In such experiments conducted at 25°C, the volatilization rates were too low to permit correlation with airflow rate of field moisture capacity. In each experiment, the major proportion of endosulfan volatilized was the ˝-isomer.

The experiment was conducted on "Jiffy Mix," a greenhouse growth media, instead of on soil. While an EPA representative apparently authorized the use of this greenhouse growth medium, its use results in a high degree of uncertainty in extrapolating results to the field. The degree and nature of degradation of endosulfan on Jiffy Mix in comparison to on soil is uncertain. The experiments lasted a total of 45 days, a period in which a sizable amount of endosulfan may have undergone metabolism in soil. Since there is no way to calculate the amount of CO_2 from metabolism processes and there were no attempts to measure degradation products, true material balances could not be calculated.

Field Dissipation

164-1 Terrestrial Field Dissipation

Overview: Three terrestrial field dissipation studies were conducted at locations in Donalsonville, Georgia, and in Tulare and Poplar, California. At each site one cropped and one

bareground plot were set. The cropped plot in Georgia was planted to tomatoes while the two cropped plots in California were planted to cotton. There was some variability from field to field in the persistence of ″- and ˇ-endosulfan, but there was relatively high consistency in the persistence of the isomers in the plots within each site. All three sites had acidic to slightly acidic pH's; therefore, probably hydrolysis was not an important dissipation route in the selected sites. In alkaline soils, it is expected that hydrolysis could contribute substantially to the overall fate of the chemicals. The two major transformation products of endosulfan were monitored in these studies: endosulfan-sulfate and endosulfan-diol. Of these, endosulfan-sulfate was the more prevalent and appeared to be more persistent.

Georgia Tomato/Soil Study (MRID 413097-02): Endosulfan (Thiodan 3EC; 2:1, ″:ˇ isomers) was applied to bareground and tomato plots on sandy loam soil in Georgia in five applications at 0.5 lb ai/A each in August-September 1987. Endosulfan dissipated from the top 5 cm of soil with the following reported half-lives:

Plot	″-endosulfan	ˇ-endosulfan	Total ″ and ˇ residues	Total ″, ˇ, and sulfate residues
bareground	47	100	90	172
tomatoes	46	91	76	155

Bareground: In the 0- to 5-cm soil depth of the bareground plot, ″-endosulfan averaged 0.588-1.092 . g/g (ppm) immediately after each of the five applications, 1.040 . g/g nine days after the last application, and gradually decreased to 0.011 . g/g at 272 days and 0.008 . g/g at 539 days. ˇ-Endosulfan dissipated more slowly. It averaged 0.456-1.126 . g/g immediately after each application. From a maximum of 2.132 . g/g on day 9 after the last treatment, it decreased thereafter to 0.033-0.047 . g/g on days 452 and 539.

Endosulfan-sulfate reached a maximum average on day 180 after the last application, at 1.220 . g/g. On day 539 (last sample interval), endosulfan-sulfate averaged 0.286 . g/g. Endosulfan-diol was a maximum average of 0.310 . g/g five days after the last treatment. It generally decreased thereafter and was last detected 180 days after the last treatment, at an average of 0.014 . g/g

Cropped plot (tomatoes): In the cropped plot, ″-endosulfan averaged 0.476 to 1.508 . g/g immediately after each treatment. From an average of 0.912 . g/g 9 days after the last treatment, it decreased gradually until day 272, when it was last detected at an average of 0.007 . g/g. ˇ-Endosulfan was observed at averages of 0.482-1.016 . g/g immediately after the five applications. After the last application, ˇ-endosulfan reached a maximum average of 1.860 . g/g 9 days later. Thereafter, it showed a general pattern of decrease to 0.015 . g/g at the last test interval (539 days after the last treatment).

The degradate endosulfan-sulfate reached a maximum average of 1.146 . g/g on day 180 after the last application. By 539 days after the last treatment (last test interval), it was an average of 0.220 . g/g. Endosulfan-diol was observed from immediately after the first application (average of 0.038 . g/g) through 120 days after the last treatment (average 0.014 . g/g), with a maximum at 9 days after the last treatment (0.418 . g/g).

California Cotton/Soil Study (MRID 414686-01): This study provides useful information on

the terrestrial field dissipation of endosulfan on loam/clay loam soil in California. The study is supplemental because the following deficiencies make interpretation of the results difficult:

a.   The harvest trash from the cotton field was not analyzed.

b.   Soil samples were not taken to a sufficient depth to show conclusively a pattern of leaching.

Thiodan® 3EC (˝ - and ˘ -endosulfan), mixed with water and sprayed aerially twice (1 month interval) at a nominal rate of 1.5 lb a.i./A/application, was applied to both cotton and bareground plots on a loam/clay loam soil in Tulare County, California. After the second application, ˝-endosulfan dissipated from the top 5 cm of the **cotton** plot with a half-life of 69 days; ˘-endosulfan dissipated with a half-life of 106 days. Total isomer (˝ + ˘) half-life was 93 days (r^2=0.90), and the half-life for total combined residues (isomers plus endosulfan-sulfate) was 142 days. On the **bareground** plot, ˝-endosulfan dissipated with a half-life of 71 days following the second application; ˘-endosulfan, on the other hand, dissipated with a half-life of 101 days. Combined ˝- and ˘-endosulfan dissipated after the second application with a registrant calculated half-life of 89 days (r^2=0.84) and the total residues had a half-life of 147 days.

Total endosulfan residues on drift cards approximately 40 m from the treated field averaged 16±15 mg/m^2 (or approximately 10% of the application rate) and 9.1±14.8 mg/m^2, following the first and second applications, respectively, indicating substantial drift 40 m from the field.

Cotton Plot: In the cotton cropped field, starting at day 29 (day 0 after the second treatment) through 478 days, endosulfan (reported as combined levels of ˝- and ˘-residues) in the 5 to 35 cm soil depth ranged from 0.006 to 0.012 ppm. In the 35 to 65 cm soil depth detections were reported at 180, 359, and 539 days after the last application, at 0.005 to 0.020 ppm. Only one sample was tested from day 1 after the last treatment; and only four of the single replicates were tested, of the 35-65 cm soil depth from 0 to 539 days after the last treatment.

Endosulfan-sulfate was first detected in the 0-5-cm soil depth at 28 days after the first treatment at an average of 0.103 ppm. It increased to an average of 0.120 ppm immediately after the second application, and 0.340 ppm by 7 days . It was a maximum average of 0.477 ppm by 63 days and was detected through the study (0.040 ppm at 568 days posttreatment).

In the 0-5 cm soil depth, endosulfan-diol averaged 0.067 ppm immediately after the first application and decreased to 0.018 ppm by 28 days posttreatment. It reached a maximum of 0.133 ppm immediately after the second application, and decreased thereafter until the day 124 posttreatment (last detection at 0.006 ppm). Immediately after the last application this degradate was detected at 0.008 ppm in the 5-35 cm and 35-65 cm soil depths.

Bareground Plot: In the bareground plot, combined ˝- and ˘-endosulfan was detected at variable concentrations in the 5 to 35-cm soil depth, and sporadically in the 3- to 6-cm soil depth. At both soil levels, maximum was at 180 days, with 0.027 ppm for the 5-35 cm soil depth, and 0.013 ppm for the 35-65 cm soil depth.

In the bareground plot, endosulfan-sulfate was detected initially in the surface 5 cm at 0.013 ppm

(average, 3 replicates) 0 days after the first treatment, at 0.160 ppm immediately after the second application, and at a maximum of 0.427 ppm at 7 days posttreatment. It was present at all sampling intervals thereafter, averaging 0.053 ppm at 539 days after the last application (last test interval).

Endosulfan-sulfate was present in the 5-35 cm soil layer of the bareground plot, with consistent detections from day 28 after the last application to day 539 (single samples, no replication) Levels were relatively low, ranging from 0.010 to 0.060 ppm. In the 35- to 65-cm soil depth only one detection of endosulfan-sulfate was reported, at day 568, at 0.060 ppm (single sample, no replicate. Only limited sampling was performed at this soil depth).

Field Runoff: No data were reported for plant tissue (cotton seed and harvest trash). The experimental field had been leveled for furrow irrigation (1% slope). Selected irrigation samples (head water) were analyzed from each irrigation event. Irrigation events were on days 4 after the first application, and 3, 28, and 38 after the second application. The volume of water discharged was 54, 625, 320,, and 100 L. The parent material, ˝- and ˇ-endosulfan and endosulfan sulfate, were detected at maximum concentrations of 0.019 ppb and 0.014 ppb, respectively, in replicate water samples from the second irrigation event. The parent material (˝- and ˇ-endosulfan) was not detected during the other irrigation events; however, endosulfan-sulfate was detected at 0.007 ppb in one replicate from the first irrigation. According to the region the monitored volumes of irrigation tailwater discharged were approximately 17, 000-100,000 L, according to the registrant. For this study, the amount of tailwater produced was greater than normal practice.

California Soil/Cotton Study (MRID 430697-01): ˝- plus ˇ-Endosulfan dissipated with an observed 50% dissipation time of approximately 7 days in bareground and vegetated cotton plots of loamy sand soil in California. The plots, located near Poplar, California, were treated twice with Thiodan 3EC at 1.5 lb ai/A each (containing ˝:ˇ at a ratio of about 2:1). The plot soil was a loamy sand soil (76.4% sand, 17.6% silt, 6.0% clay, 1.11% OM, pH 6.8). The applications were made 29 days apart in mid July and mid August using ground equipment. The rapid dissipation was mainly due to the degradation of the ˝-isomer. The calculated half-lives for ˝- and ˇ-endosulfan were as follows:

	Post-application one		Post-application two	
	˝-endosulfan	ˇ-endosulfan	˝-endosulfan	ˇ-endosulfan
bareground/da	6	23	11	36
cotton crop/da	7	19	6	63

Cotton Plot: The following averages are of three replicates. In the top 0-6 inches of the plot cropped with cotton, ˝-endosulfan averaged 0.271 ppm immediately after application 1, 0.082 ppm after 7 days, 0.274 ppm immediately after the second application, 0.124 ppm 3 days after the second application, and 0.007 ppm 30 days after the second application.

In the top 0-6 inches of the same plot, ˇ-endosulfan reached 0.166 ppm immediately after the first application, 0.082 ppm 14 days later, 0.217 ppm 1 day after the second application, 0.082 ppm 30 days after the second application, and 0.006 ppm 540 days after the second (last test interval).

In the same soil level, endosulfan-sulfate was detected from day 1 post-application 1 through 240

days (last test interval). The maximum level was observed on day 14 post application 2, with 0.243 ppm. Another maxima was seen on day 180 after the second application, with 0.216 ppm. After 540 days post application 2, endosulfan-sulfate decreased to 0.020 ppm.

Only sporadic detections were observed in the 6-12 inch soil level around the second application and 120 days after the second application. Average (of three) levels were ¸ 0.018 ppm. Very few additional detections were reported below the 6-12 inch soil level, which do not appear to indicate that there was extensive leaching in this study.

Bareground Plot: In the top 0-6 inches of the bareground plot, ˝-endosulfan averaged 0.230 ppm (all values are averages of three measurements) immediately after the first application, 0.155 ppm after 7 days, 0.398 ppm immediately after the second application, 0.131 ppm 3 days after the second application, and was last detected on day 150 after the second application at 0.008 ppm.

In the top 0-6 inches of the same plot, ˇ-endosulfan was 0.140-0.162 ppm at 1-7 days posttreatment 1, 0.310 ppm immediately after the second application and decreased thereafter slowly to a minimum of 0.005 ppm 540 days after the second application.

Endosulfan-sulfate was present in the 0-6 inch soil level from the time immediately after the first treatment (0.018 ppm). It reached a maximum of 0.231 ppm 10 days after the second application, and , in general, it decreased slowly thereafter. On days 390, 450, and 540 after the second treatment, endosulfan-sulfate was 0.011-0.015 ppm.

In general, very few detections were reported in the lower soil horizons. On days 0 and 1 after the second treatment, low levels of ˝- and ˇ-endosulfan were observed in the 6-12 inch soil level. Two other detections, one of ˝- and other of ˇ-endosulfan were observed at ¸ 0.006 ppm. No detections were reported below the 12 inch soil horizon.

Runoff

A non-guideline runoff study (MRID# 449036-01) provided useful supplemental information about the runoff potential and behavior of endosulfan (mixture of ˝- and ˇ-isomers). Endosulfan was applied 3 times at monthly intervals at a rate of 1 lb ai/A each to a cotton crop planted on a Lawrence silt loam soil (hydrologic group C) on a 4-5% slope in Richmond, Kentucky. Triplicate test plots evaluated the effect of buffer width on endosulfan runoff. A rainfall simulator added 1.2 inches of water per hour for 2 hours on the day after each application. An additional simulated rainfall at the same level was applied following a post-harvest cultivation.

During the first rainfall simulation, the concentration of endosulfan in the edge-of-field runoff was greatest with 50-foot buffer and least with the unbuffered plot. During the second and third runoff events, the anticipated trend of decreasing endosulfan load with increasing buffer width was observed. No explanation was provided for the anomalous results.

Following the first runoff event, the concentrations in the runoff water ranged from 112 - 181 ppb for the plot without a buffer zone (average 147 ppb); 99 to 232 ppb (avg. 183 ppb) for the plot with a 25 ft. buffer; and 160 to 234 ppb (avg. 203 ppb) for the plot with a 50 ft. buffer. In a plot with an

unmaintained 25 ft. buffer, concentrations in runoff varied from 72 to 141 ppb (average 112 ppm).

Following the second runoff event, the concentrations in the runoff water ranged from 182-266 ppb for the plot without a buffer zone (avg. 228 ppb); 149-166 ppb (avg. 160 ppb) with a 25 ft. buffer; and 140-193 ppb (avg. 163 ppb) with a 50 ft. buffer. In a plot with an unmaintained 25 ft buffer, the values in the runoff varied from 137-170 (avg. 150 ppb).

Following the third runoff event, the concentration in the runoff water ranged from 226-279 ppb (avg. 249 ppb) for the plot without a buffer zone; 110-246 ppb (avg. 186 ppb) with a 25 ft. buffer; and 122-161 ppb (avg. 140 ppb) with a 50 ft. buffer. In a plot with an unmaintained 25 ft. buffer , the values in the runoff water varied from 118 to 170 (average 145 ppb).

The following table summarizes the range in concentrations in the runoff from each buffer (averaged), the endosulfan transport as the percentage of applied for each buffer, and the range in percentage of endosulfan transported on sediment.

Type of buffer	range in concentrations that were collected in the runoff from each/ppb	endosulfan transport as the percentage of the applied for each buffer plot	range in percentage of endosulfan transported on sediment
0 ft.	147-249	2.8-7.7	55.7-83.1
25 ft.	160-186	4.4-5.8	50.7-80.7
50 ft.	140-203	4.6-6.7	43.3-83.2
25 ft. UM*	112-150	2.5-5.9	NA

UM = Unmaintained buffer

A 1989 study conducted in South Carolina (MRID 413097-01) was "considered technically strong in many ways" in a 1993 review, but had limited applicability because the chosen soil type was not particularly vulnerable to runoff and the irrigation used to simulate rainfall was not applied at a rate sufficient to generate significant runoff. In addition, data and results were not clearly presented. These flaws are such that generalizations regarding the effectiveness of a buffer cannot be assessed. Thus, while the South Carolina study might suggest that when endosulfan is applied to a soil that is not particularly prone to runoff and is exposed to rainfall that is not particularly intense enough to result in runoff, a 200-foot buffer may result in reductions in endosulfan concentrations of up to two orders of magnitude, the flaws make it difficult or impossible to apply this study to other areas.

164-2 Aquatic Field Dissipation

No guideline studies conducted. A non-guideline study submitted by the registrant in 1989 evaluated the fate and effects of endosulfan in two Georgia ponds adjacent to tomato fields (MRID 411641-01). This study provided supplemental information on the fate of endosulfan under these conditions. While the study was conservative in some aspects (for instance, the minimum distance of the treated fields to the pond ranged from 15 to 50 feet, less than the current 300-foot separation specified on the label), the watershed soils and rainfall/ irrigation rates were not necessarily conservative in terms of runoff potential. However, it does provide some useful information. The persistence of the isomers in

the soil was sufficient to result in accumulations between applications and to contribute ˝- and ˘- endosulfan and endosulfan-SO$_4$ in runoff water at least five months after the last application. Endosulfan reached the pond via spray drift and runoff, with the highest concentrations in runoff occurring in the first event after the last application. Endosulfan sulfate in the pond resulted from runoff transport and transformation of the parent in the pond. Endosulfan dissipated rapidly from the water column of the ponds, apparently due to a combination of alkaline hydrolysis (pH of the ponds varied widely from 5.7 to 10) and sorption to sediment. Maximum concentrations of endosulfan isomers and endosulfan sulfate in the sediment were one to two orders of magnitude greater than that of the water column. Neither ˝- nor ˘-endosulfan were found in fish samples; however, endosulfan-sulfate was found at a maximum of 22.5 .g/Kg.

Accumulation

165-4 *Accumulation in Fish* (Acc. No. 05003053, and 05005824)

The registrant reported K$_{OW}$ of 55500 for ˝-endosulfan and 61400 for ˘-endosulfan (MRID# 414215-03). These values would predict a relatively high potential of such chemicals to bioaccumulate in fish. The registrant submitted two literature articles that provide some information about the bioaccumulation potential of endosulfan in certain marine animals. The studies, conducted in 1977, do not meet current guidelines and results should be regarded only as supplemental.

In one study, ˝-endosulfan (this isomer only) bioconcentrated on mussels [at 10°C, exposed for 170 hours, with 48 hours of depuration], with a bioconcentration factor of 600. It was reported that equilibrium was reached within 50 hours. The half-life of depuration was reported to be 33.8 hours.

In the other study, ˝- and ˘-endosulfan bioaccumulated on striped mullet (Mugil cephalus) [at 22°C, with 28 days of exposure, followed by 28 days of depuration], with bioconcentration factors of 2,429 for edible tissue and 2,755 for whole body. Most of the uptake occurred within the first 48 hours of exposure. No parent residues were detected after 48 hours of depuration. Tissue analysis generally revealed the presence of endosulfan-sulfate rather than ˝- or ˘-endosulfan.

APPENDIX B: SUMMARY OF SELECTED SCIENTIFIC LITERATURE USED IN SUPPORT OF THE ENDOSULFAN ASSESSMENT

This appendix contains a review of various representative literature articles that complement the information available to EFED from the studies submitted by the registrant.

Endosulfan is an insecticide typically applied as a mixture of 70% ″-isomer and 30% ˇ-isomer on a variety of fruits, vegetables, cereals, and cotton. The isomers have different physicochemical properties: ″-endosulfan has lower solubility and higher volatility than ˇ-endosulfan. Contrary to reports of previous investigators, recent data suggest that the ˇ-isomer is symmetrical while the ″-isomer is a mixture of two structurally indistinguishable molecules. The transformation of ˇ to ″ is energetically favored and is expected to be the predominant isomeric conversion process in the environment. The ″-isomer is relatively more hydrolytically- and photolytically-stable in aqueous solutions than the ˇ-isomer. In seawater sediment-water system, the ″-species is more persistent. However, the ˇ-species is more persistent in soils. Under typical application conditions, endosulfan sulfate was observed to be the major transformation product. Endosulfan sulfate is reported to have a toxicity to houseflies similar to that of the parent endosulfan (O'Brien, 1967). Endosulfan diol was reported to be the main degradate under anaerobic conditions. Environmental monitoring results indicate that atmospheric transport is responsible for the detection of endosulfan in rain, snow and arctic air. Both endosulfan isomers and endosulfan sulfate were detected in several rivers and groundwater within the vicinity of endosulfan application.

Introduction

Endosulfan (hexachloro-1,5,5a,6,9,9a-hexahydro-6,9-methano-2,4,3-benzodioxathiepin-3-oxide) is a broad spectrum contact insecticide that is used in a wide variety of vegetables, fruits, cereals, and cotton. End-use products contain two forms of endosulfan -- ″-endosulfan or endosulfan I and ˇ-endosulfan or endosulfan II -- in a typical ratio of 70:30 (″:ˇ). The relative abundance of the two isomers can actually range from 64 - 67 % of ″ and 29 - 32 % of ˇ (Royal Society of Chemistry, 1983). The environmental fate properties of endosulfan inherently depends on the structural relationship of ″ and ˇ isomers.

Three sections on endosulfan are presented in the literature review. The first one describes the structural configurations and isomeric conversion of ″- and ˇ-endosulfan. The second one addresses the environmental fate characteristics which cover the physicochemical properties and relevant kinetic information on some chemical/biological processes for the two isomers. The last one deals with atmospheric transport and some field monitoring data for endosulfan detected in rain, snow, surface waters, and groundwater.

This preliminary review was undertaken to gather additional relevant fate information and to improve EFED's understanding of the fate and transport characteristics of endosulfan in different environmental matrices that are needed in human health and ecological risk assessments.

Endosulfan Isomers And Isomeric Conversion

The crystal structures of ″- (structure III, Figure B-1) and ˇ-endosulfan (structure II, Figure 1) have been considered by previous investigators (Smith et al, 1977; Forman et al, 1965) to be

symmetrical. However, this symmetry concept for the two molecular conformers has been questioned on the basis of incorrect structural assignments. The X-ray crystallographic and Nuclear Magnetic Resonance (NMR) temperature data from a recent investigation of Schmidt and co-workers (1997) indicated that the ″-isomer is a mixture of two structurally indistinguishable asymmetrical molecules while the ˇ-isomer is symmetrical as shown in Figure B-1. The main difference between the two isomers lies in the 2,4,3-benozodioxathiepin-3-oxide portion of endosulfan molecule.

I: α-endosulfan (first twist chair form)

I: α-endosulfan (second twist chair form)

II: β-endosulfan (symmetrical)

III: α-endosulfan (incorrect)
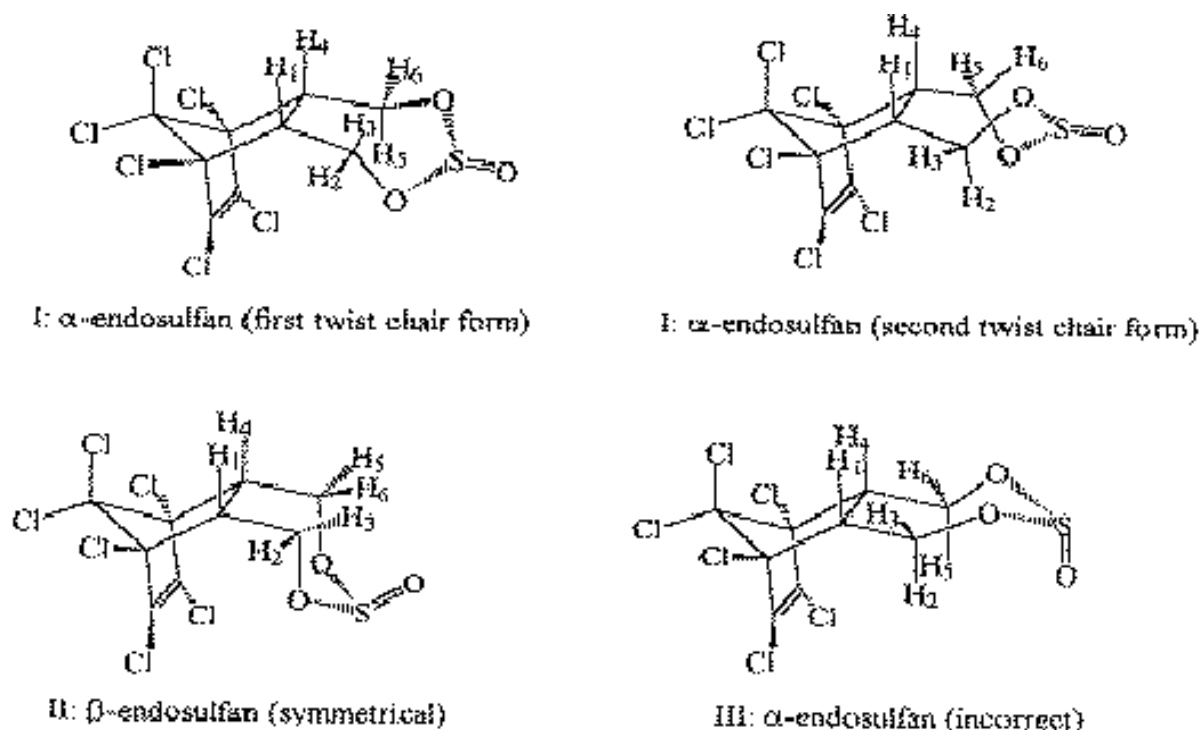
Figure B-1

Endosulfan has been reported to undergo conversion between the two isomers. Hydrolysis or participation of water has been postulated to cause the isomeric equilibrium conversion (Miles and Moye, 1979; Chopra and Moahfouz, 1977). Interconversion of the two isomers has been postulated to occur in the environment. The conversion of the ″-isomer to the ˇ-isomer often predominates because the beta isomer is more stable. However, more recent experiments by Schmidt et al (1997) indicate that ˇ conversion to ″ is much more thermodynamically favorable because the transition is from a symmetrical ˇ form to a asymmetrical ″ species. The reverse process, asymmetrical ″ to symmetrical ˇ, is energetically unfavorable. Thus, the ˇ * ″ isomeric conversion would be the predominant process that will be considered in evaluating the physicochemical and fate properties of endosulfan.

Environmental Fate Characteristics

The structural differences and conversion between the two isomers are important in understanding the fate processes and estrogenic effects of endosulfan in relation to endocrine mimic activity and binding (Soto, 1994). Certain data indicate that the ˝-isomer is relatively more toxic than the ˘-isomer. For instance, Antonious et al (1998) reported rat acute oral LD_{50} values of 76 mg/kg for ˝-endosulfan and 240 mg/kg for ˘-endosulfan; Cole et al (1994) found LD_{50} for houseflies of 1.3 ug/g for ˝ and 3.2 ug/g for ˘. The reported toxicity difference and the observed isomeric ratio in different environmental compartments may be linked to the differences in certain physicochemical properties of the isomers.

Physicochemical Properties: The important physical and chemical properties of ˝- and ˘-isomers are summarized in Table B-1. The properties include melting point (mp), solubililty, vapor pressure (vp), and Henry's Law Constant (K_H). The mp of the ˘-isomer is higher than that of the ˝-isomer by about a factor of two. For solubility, the first two sets of data indicate that the ˝ is more soluble than the ˘. However, the next two sets of data with relatively higher magnitude indicate otherwise. The difference between the two sets of data might be attributed to the sample type reported for the two isomers. For instance, the solubility of ˝ (3.4 ppm) and ˘ (18.8 ppm) were estimated for subcooled liquid of endosulfan whereas the other solubility values (˝ = 0.53 and 1.54 ppm; ˘ = 0.28 and < 1 ppm) were probably obtained from the crystalline form of endosulfan. The vp of ˝ is almost two times that of ˘. The higher vp of ˝ is reflected in the values reported for K_H which is a measure of the volatilization potential of a chemical from open water bodies. The values suggest that ˝ is relatively more volatile than ˘. The first three set of values of K_H were calculated from the ratio of vapor pressure to water solubility to assess the air-water exchange of chemicals. This indirect way of estimating the air-water distribution coefficient or K_H relies on the accuracy of the respective vapor pressure and solubility values used in the calculation. The direct and best approach is to actually measure K_H. The K_H values from Rice et al (1997) reported in Table B-1 are experimentally derived constants determined by a using a wetted wall column device. These experimental values suggest that the ˝-isomer has enough potential to volatilize from surface water bodies. Indeed, some investigators (Antonious and Byers, 1997) describe endosulfan as semivolatile.

Table B-1. Physicochemical Properties of Endosulfan Isomers

Parameter	˝-endosulfan	˘-endosulfan	Reference
melting point	70 - 100 ^{0}C	207 - 209 ^{0}C	Montgomery, 1993
	108 - 110 ^{0}C	208 - 210 ^{0}C	Devito and Docter, 1998
water solubility	0.53 ppm	0.28 ppm	Montgomery, 1993
(20 - 25 ^{0})	1.5 ppm	< 1 ppm	Devito and Docker, 1998
	2.29 ppm	31.1 ppm	Guerin and Kennedy, 1992
	2.4 ppm	18.8 ppm	Cal'd for subcooled liquid*
vapor pressure	0.006 Pa	0.003 Pa	Guerin and Kennedy, 1992
(20 - 25 ^{0}C)	6.2 mPa	3.2 mPa	McConnell et al, 1998
	10^{-5} mm Hg	10^{-5} mm Hg	Montgomery, 1993

Table B-1. Physicochemical Properties of Endosulfan Isomers

Parameter	α-endosulfan	β-endosulfan	Reference
Henry's Law Constant	1.07 Pa m^3 mol^{-1}	0.04 Pa m^3 mol^{-1}	Guerin and Kennedy, 1992
	6.6 Pa m^3 mol^{-1}	0.87 Pa m^3 mol^{-1}	McConnell et al, 1998
	6.7 E-6 atm m^3 mol^{-1}	6.2 E-7 atm m^3 mol^{-1}	Cotham and Bidleman, 1989
	6.65E-5 atm m^3 mol^{-1}	9.34E-6 atm m^3 mol^{-1}	Rice et al, 1997**
	2.72E-3 (unitless)	3.60E-4 (unitless)	Rice et al, 1997**
	2.79E-4 (unitless)	2.58E-5 (unitless)	Cotham and Bidleman, 1989

* $Sol_{subcooled} = Sol_{solid} / \exp[-0.023 (T_{mp} - 298)]$ \qquad **Experimental Values

Environmental Fate Behavior: The different physicochemical properties of the two isomers would be expected to influence the environmental fate behavior of endosulfan. The se studies supplement OPP's understanding of the fate of endosulfan and its transformation products in the environment.

Volatilization: In controlled experiments conducted in a wind tunnel by Rudel (1997), 60% of the applied endosulfan volatilized from the surface of French beans within 24 hours of application. In contrast, 12% of the applied endosulfan volatilized from the soil surface. In comparison with other relatively volatile pesticides, endosulfan was more volatile than methyl parathion and fenpropimorph but less volatile than lindane and trifluralin.

Rice et al. (1999) measured the volatilization fluxes of six pesticides from freshly-tilled soil. These pesticides, ranked from increasing to decreasing volatile flux losses, were: trifluralin > α-endosulfan > chlorpyrifos > metolachlor > atrazine > β-endosulfan. 34.5% of the applied α-endosulfan and 14.5% of the applied β-endosulfan were lost by volatilization from the soil.

Abiotic Degradation: Data on the stability or persistence of the endosulfan isomers in the different environmental media are presented in Table B-2. The persistence is assessed in terms of the half-lives associated with the degradation processes. In sterilized and buffered aqueous solutions (pH 4.5, 7.0, and 9.5), α-endosulfan is relatively more hydrolytically stable compared to β-endosulfan. The low half-lives (about 1 hr. for both isomers) at pH 9.5 imply that both isomers would readily hydrolyze under moderately to strongly alkaline aquatic environments. The solution photolysis half-lives in Table B-2 indicate that both α- and β-endosulfan are relatively more inert to UV radiation in aqueous solution than in hexane solution. In both solutions, the α-isomer is more stable than the β-isomer.

Table B-2. Degradation of endosulfan in different environmental media.

Process	Half-Life	
	α-endosulfan	β-endosulfan
Hydrolysis (30 ^{0}C)		
Sterilized pH 4.5	93.3 days	87.7 days
pH 7.0	27.5 days	23.5 days
pH 9.5	0.043 day	0.036 day
Unsterilized		
pH 7.0	7.04 days	7.30 days

Table B-2. Degradation of endosulfan in different environmental media.

Process	Half-Life	
	˝-endosulfan	ˇ-endosulfan

Solution Photolysis (Hg Lamp, 25 °C)
    Water
    Hexane
	
	 47.8 hr
	 7.0 hr
		
		 32.9 hr
		 3.0 hr

Seawater Dissipation
    Unsterilized
       pH 8.0
       pH 8.05
    Sterilized
       pH 8.0
       pH 8.2
	
	 4.9 days
	 4.4 days
	
	 3.1 days
	 1.9 days
		
		 2.2 days
		 2.0 days
		
		 2.0 days
		 1.3 days

Seawater/sediment system (pH 7.3 - 7.7)	22 days	8.3 days

Source: Singh et al, 1991; Cotham and Bidleman, 1989

Fate in Terrestrial Environments: The environmental fate behavior of the two isomers in the terrestrial environment is different. Singh et al (2000) studied the degradation of endosulfan using sieved Indian soils that were moistened to field capacity and incubated at 28 ± 2 °C. As summarized in Table B-4, ˝-endosulfan degraded more readily than ˇ-endosulfan. Endosulfan sulfate was similarly- to slightly-more persistent than ˇ. Similar results were obtained by Antonious and Bayers (1997) who reported that ˇ is relatively more persistent than ˝ from their investigation on the fate of endosulfan under field conditions. In both studies, endosulfan sulfate was found to be the major degradate. O'Brien (1967) reported that endosulfan sulfate has a toxicity to houseflies almost identical with endosulfan itself.

Table B-3. Half-life values of endosulfan isomers in Indian soils (Singh et al, 2000).

Soil (non-sterilized)	Half-life (days)		
	˝-endosulfan	ˇ-endosulfan	endosulfan sulfate
Alfisol	55	256	277
Vertisol	27	44	25
Mollisol	17	32	35
Aridisol	42	46	62

The microbial degradation of endosulfan under anaerobic systems proceeds with a different metabolic route. Montgomery (1993) cited a study in which endosulfan diol was formed from ˝-endosulfan in soils under anaerobic conditions. Recently, Guerin (1999) conducted an investigation on the transformation of ˝-endosulfan by an indigenous mixed population of anaerobic microorganisms from low-oxygen soils and sediments. The sediments were taken from sullage pits and tailwater drains near cotton fields in New South Wales, Australia, and nearby seabed sediments. In anaerobic systems that were buffered between 6.8 and 7.2, more than 85% of ˝-endosulfan degraded over 30 days, with endosulfan-diol as the main degradation product. Guerin (1999) noted that the primary pathway of degradation in anaerobic conditions is the opening of the cyclic diester ring and may be catalyzed by a

non-specific enzyme. Endosulfan sulfate is not expected to be formed under this pathway.

Fate in Water: Both isomers exhibited short dissipation half-lives in unsterilized seawater (Cotham and Bidleman, 1989; Table B-3). However, in sterilized seawater, both isomers have lower half-lives. The difference in half-lives between sterilized and unsterilized systems might be attributed to the possible physical and biological changes brought about by autoclaving the seawater or a shift in pH. In the seawater/sediment system, the half-lives were calculated from the total quantity of the isomers remaining in the sediment and aqueous phases. The degradation observed in the sediment/water system are relatively longer than those in seawater alone.

Barry and Logan (1998) reported that 6 to 12% of the endosulfan applied to tanks simulating a pond microcosm remained in the sediment in toxic form (˝- or ˇ-endosulfan or endosulfan sulfate) after 10 weeks. The dissipation half-life of endosulfan in the water column was approximately 24 hours. A portion of the applied endosulfan may have dissipated by volatilization because the tanks were aerated (a loss that may be exaggerated in the controlled system compared to the natural environment). Other routes of dissipation appear to be degradation by bacteria, uptake by macrophytes, and absorption by algae. The authors speculated that dying plant tissues may be a source of slow release of endosulfan back into the pond microcosm, but did not investigate that source in this study. Endosulfan concentrations in water increased as algae levels decreased, suggesting that endosulfan undergoes reversible binding with the algal populations.

Environmental Monitoring (˝-endosulfan, ˇ-endosulfan, and endosulfan-sulfate)

Several investigators have monitored the levels of the two endosulfan isomers and the major degradate endosulfan sulfate in different environmental matrices. Detections in rain, snow and air indicate that atmospheric transport is an important long-distance route of dissipation of endosulfan. The two isomers were also reported to be found in rivers and groundwater of areas associated with endosulfan applications.

Atmospheric Transport

Rain and Snow: McConnell et al (1998) explored the possible atmospheric transport of various pesticides by collecting winter-spring precipitation (rain and snow) from Sequoia National Park at two different elevations, and from Lake Tahoe basin. Since the adjacent Central Valley of California is one of the heaviest pesticide use areas in the USA, it was expected that some of those pesticides would be present in some of the sampling locations.

The Lake Tahoe was sampled from two stations. Both surface and deep water samples were taken. Rain and snow were sampled from Ash Mountain (near the entrance to the Sequoia National Park, Ward Creek (west of Lake Tahoe), and , at Lower Kawea in the Sequoia National Forest.

The ˝- and ˇ-endosulfan were analyzed using a GC, coupled with MS, in the selected ion monitoring mode. The LOD's were 0.075-0.076 ng for the Lake Tahoe water, and 0.14-0.19 ng for the snow and rain. Table B-4 summarizes the results obtained at those locations. The Ash Mountain samples were all rain, while the other samples were snow. Up to seven samples were collected at each of the three sites identified (at different times of the year).

Cotton is the major crop in the Central Valley, with endosulfan usage being higher around August. This factor may explain the seasonal differences in detection (Summer vs. Winter). Generally, α-endosulfan shows higher concentrations, compared to β-endosulfan, which may partly reflect the fact that the commercial mixture comes in ratios of approximately 7:3 (α:β). However, factors such as air/water partitioning (Henry's Law Constant), vapor pressure, and others can also affect the distribution of these compounds in the rain, snow and air. The authors believe that further research is needed to discern better the processes controlling the fate of endosulfan in the environment.

Table B-4. Concentration of α- and β-endosulfan in rain and snow from the Sierra Nevada mountains.

Site/Date Collected	α- endosulfan (ng/L)	β-endosulfan (ng/L)
Ash Mountain, Sequoia National Park (rain)		
12/14/95	1.6	0.64
01/18/96	<0.035	0.23
01/24/96	0.86	0.27
02/01/96	<0.19	<0.25
02/26/96	6.5	1.4
03/30/96	<0.31	<0.42
04/02/96	<0.13	<0.17
Lower Haweah, Sequoia National Park (snow)		
01/18/96	0.97	<0.077
02/06/96	0.93	0.19
02/20/96	2.8	0.26
03/05/96	1.0	<0.012
04/02/96	3.0	0.46
Ward Creek, Lake Tahoe basin (snow)		
12/20/95	1.0	<0.012
02/02/96	1.1	<0.012
04/07/96	<0.035	<0.012

Arctic Air: Halsall et al (1998) performed a multi-year (1992-1994) and multi-site (Canadian and Russian Arctic) study off atmospheric measurements of several organohalogen pesticides. The sampling locations were Tagish (Canada), Alert (Canada) and Dunai (Russia). At each site filters and polyurethane foam plugs were used to collect the various materials to be tested. Endosulfan was one of the pesticides present in the Arctic air at relatively high concentrations. Hexachlorobenzene and hexachlorocyclohexanes were the most predominant compounds in the atmosphere; endosulfan and the chlordanes were the next most predominant.

Table B-5 provides mean and range of concentrations of endosulfan. Even though this is not shown in the table, there appeared to be some correlation between the concentration of endosulfan and the time of the year at which it is normally applied (i.e. the concentration of endosulfan in the Arctic air was higher during the Summer, even though the actual temperatures at the sampling sites averaged only about 5°C during the Summer).

Table B-5. Arithmetic Mean (range) of endosulfan (˝- + ˘-isomer) in arctic air (filter + polyurethane foam plug)

Site/Time	endosulfan (pg m^{-3})
Canadian Ice Is. June 1987	3.4 (1.8-5.0)

Alert
  1993
  1994
	3.60 (0.02-9.42)
	4.84 (0.07-16.2)

Tagish
  1993
  1994
	5.76 (0.08-15.3)
	8.33 (0.08-88.6)

Dunai 1993	2.99 (0.05-7.18)

Surface Water

Patuxent and Choptank Rivers (MD): Lehotay et al (1998) monitored two tributaries of the Chesapeake Bay. The monitoring included water and oyster samples in the Patuxent and Choptank Rivers throughout 1997. Testing was performed for various pesticides, among which Endosulfan (˝- and ˘-), and Endosulfan sulfate were included. Various polycyclic aromatic hydrocarbons's (PAH's), and organochlorines (OC's) were also monitored. This study was designed to determine the concentrations of the various pesticides during the agricultural season. Sampling occurred weekly during the spring, where the concentrations were taken at a depth of 3.7 m over the area where the oysters were collected.

The analysis involved separation of the analytes and GC/MS for quantitation and identification. The LOD for oyster samples was <5 ng/g (wet weight), and <5 ng/L for the water samples. Eighteen common analytes were detected in both rivers, including endosulfan (˝- and ˘-, and endosulfan sulfate).

In the waters of the Patuxent River (Table B-6), the concentrations of ˝-endosulfan ranged from 0.49 to 5.6 ng/L (average 0.8±0.3); the concentration of ˘-endosulfan ranged from 0.29 to 35 ng/L (average 1.0±0.8); endosulfan sulfate ranged from 0.18 to 4.0 ng/L (average of 0.5±0.3). In the Choptank River, ˝-endosulfan ranged from 0.15 to 44 ng/L (average 0.4±0.3), ˘-endosulfan ranged from 0.15 to 225 ng/L (ave. 0.5±0.4; some results were excluded to calculate the average). Endosulfan-sulfate concentrations ranged from 0.17 to 0.26 ng/L (average 0.29±0.09 ng/L). Only the oyster samples from the Patuxent River had detectable levels of endosulfan I, II, and sulfate.

Table B-6. Surface water concentrations of ″- , ˘- endosulfan, and endosulfan sulfate in Patuxent River and Choptank River.

Sampling Date	Concentration, ng/L, Patuxent River			Concentration, ng/L, Choptank River		
	″-isomer	˘-isomer	endosulfan sulfate	″-isomer	˘-isomer	endosulfan sulfate
2/13	NQ*	NQ*	NQ*			
3/13	NQ*	NQ*	NQ*			
4/14	1.2	2.6	1.4			
4/22	1.7	2.3	0.99			
4/29	0.58	0.66	0.36			
5/8	0.80	1.8	0.85			
5/15	0.78	1.3	0.62			
5/22	0.83	1.0	0.54			
5/27-29	0.56	0.60	0.28	0.32	0.50	0.31
6/4-6	0.93	1.0	0.65	0.26	0.39	0.34
6/10-11	0.64	0.51	0.38	0.32	0.40	0.36
6/18-19	0.49	0.29	0.18	0.18	0.19	0.19
6/24-25	0.63	0.88	0.44	0.15	0.15	0.17
7/1-2	0.51	0.34	0.19	0.26	0.26	0.21
7/15-17	0.57	0.36	0.26	0.42	0.38	0.33
7/29-30	0.75	0.76	0.49	0.31	0.48	0.30
8/12-14	0.68	0.50	0.31	2.7**	5.0**	3.6**
8/26-27	1.4	2.8	0.97	0.40	0.84	0.40
9/9-10	5.6**	35**	4.0**	44**	225**	26**
10/14-16	0.49	0.40	0.19	0.90	0.21	0.18
11/11-12	0.52	0.37	0.26	0.91	1.4	0.42
Ave.±SD	**0.8 ±0.3**	**1.0±0.8**	**0.5±0.3**	**0.4±0.3**	**0.5±0.4**	**0.29±0.09**

* NQ = detected but not quantified

** not included in average calculation

Susquehanna River (PA): The Susquehanna River provides 90% of the fresh water flow to the upper half of the Chesapeake Bay. The river watershed has a large drainage area, with 47% of its lower portion in agricultural land. Liu et al (1998) conducted surface water monitoring for endosulfan and other pesticides, collecting samples at the mouth of Susquehanna River every 9 days for more than a year (2/21/97 - 3/28/98) for a total of 40 samples. The analytical results for endosulfan isomers and endosulfan sulfate are summarized in Table B-7. The average concentration of ˘-endosulfan is about three-and-half times higher than that of ″-isomer, which may be attributed to the relatively higher volatilization loss of the ″-species and higher water solubility of the ˘-species. Endosulfan sulfate has the lowest average value; however, the transormation product has the highest frequency of detection.

Table B-7. Endosulfan Monitoring Results for Susquehanna River			
Parameter	″-endosulfan	˘-endosulfan	endosulfan sulfate
MDL* (ng/L)	0.12	0.19	0.29
Detection (%)	37	57	72
Maximum (ng/L)	24	180	23
Average (ng/L)	3.1	7.4	1.5

* MDL = Method Detection Limit

Yazoo River Basin (MS): Endosulfan was among the persistent organic pollutants and cotton herbicides and insecticides detected in Mississippi Delta streams (Yazoo River drainage basin) within the cotton-growing region of Mississippi (Zimmerman et al, 2000). In addition to endosulfan, the persistent organic pollutants aldrin, chlordane, DCPA, DDT, dieldrin, endrin, heptachlor, mirex, nonachlor and toxaphene, and the insecticides chlorpyrifos and hexachlorocyclohexanes were also detected in five streams sampled in 1996 and 1997.

Florida Bay Joe Bay (FL): Between 1994 and 1997, ˝-endosulfan was detected in bivalves in the estuarine Florida bay at concentrations ranging from 9 to 89 ng/g (Wade et al, 1998). ˘-endosulfan was detected in concentrations ranging from 1.7 to 6.3 ng/g. Concentrations were greatest in 1994 and lowest in 1997. Because the sample collection time did not coincide with the time of maximum application, the reported concentrations may not reflect the maximum yearly concentrations of endosulfan in these estuary waters. The authors noted that while endosulfan is reported to have been responsible for more fish deaths in US estuaries and coastal waters between 1980 and 1989 than any other currently-used pesticide, analytical measurement problems make quantification of endosulfan difficult.

Outside the United States: Reyes et al (1999) reported that endosulfan, BHC, aldrin, and parathion were the most frequently detected pesticides in two coastal ecosystems near agricultural areas in northwest Mexico. Endosulfan was one of two organochlorine insecticides, along with lindane, detected in low concentrations in ground and river water from the Danube plain of Bulgaria (Balinova and Mondesky, 1999). The herbicides atrazine, alachlor, 2,4-D, and metolachlor were most often detected in the study.

Endosulfan was detected in greater than 20% of river water samples (85 samples) taken in the Choluteca River basin of Honduras; only heptachlor and chlorpyrifos were also detected at a similarly high frequency (Kammerbauer and Moncada, 1998). Endosulfan was detected in approximately 10% of 50 well/lagoon water samples; heptachlor was detected in 20% of the samples while aldrin, dieldrin, chlorpyrifos, and propiconazole were detected at frequencies similar to endosulfan. Endosulfan was detected in roughly 8% of 129 soil samples taken in the basin; only dieldrin and DDT were detected in higher frequencies. The highest concentration of endosulfan in the water samples was 0.06 mg/kg; most detections were between 0.01 and 0.02 mg/kg. Endosulfan was also detected in fish tissue and sediments sampled from two lagoons.

International Incidents

Endosulfan caused a major fish kill in the Rhine river in June 1969, with measured concentrations as high as 0.1 mg/L (Gupta and Gupta, 1979). Sediment-bound endosulfan in the Rhine River continued to affect fish as recently as 1986, when endosulfan-induced changes in gut epithelial tissue were associated with enhanced toxicity of other chemical pollutants released into the river at Basel, Switzerland (Braunbeck and Appelbaum, 1999). In 1999 Australian beef was rejected for export because of excessive residues of endosulfan that resulted from cattle grazing on pastures contaminated from spray drift from neighboring cotton fields treated with endosulfan (World Crop Protection News, 1999). Also in 1999, beef in Puerto Rico was found to be contaminated with endosulfan.

References

Antonious, G. F. and M. E. Byers. 1997. Fate and Movement of Endosulfan under Field Conditions. Environ. Toxicol. Chem. 16(4): 644 -649.

Antonious, G. F., M. E. Byers and J. C. Snyder. 1998. Residues and Fate of Endosulfan on Field-Grown Pepper and Tomato. Pestic. Sci. 54: 61-67.

Balinova, A.M., and M. Mondesky. 1999. Pesticide contamination of ground and surface water in Bulgarian Danube plain. J. Envir. Sci. And Health (B) 34:33-46.

Barry, M.J., and D.C. Logan. 1998. The use of temporary pond microcosms for aquatic toxicity testing: direct and indirect effects of endosulfan on community structure. Aquatic Tox. 41:101-124.

Braunbeck, T. and S. Appelbaum. 1999. Ultrastructural alterations in the liver and intestine of carp *Cyprinus carpio* induced orally by ultra-low doses of endosulfan. Dis. Aquatic Organ. 36(3): 183 - 200.

Chopra, N.M. and A.M. Mahfouz. 1977. Metabolism of endosulfan I, Endosulfan II, and Endosulfan Sulfate in Tobacco Leaf. J. Agric. Food Chem. 25: 32-26.

Cole, L.M., M.A. Saleh and J.E. Casida. 1994. House fly Head GABA-Gated Chloride Channel: $[^3H]^{''}$ - Endosulfan Binding in Relation to Polychlorocycloalkane Insecticide Action. Pestic. Sci. 42: 59-64.

Cotham, W.E. and T.F. Bidleman. 1989. Degradation of malathion, endosulfan, and fenvalerate in seawater and seawater/sediment microcosms. J. Agric. Food Chem. 37: 824-828.

Forman, S.E., A. J. Turbetaki, M.V. Cohen, and R.A. Olofson. 1965. Conformatinal Equilibria in Cyclic Sulfites and Sulfates: The Configurations and Conformations of the Two Isomeric Thiodans. J. Org. Chem. 30: 169-175.

Guerin, T.F. 1999. The anaerobic degradation of endosulfan by indigenous microorganisms from low-oxygen soils and sediments. Environmental Pollution 106: 13-21.

Guerin, T.F. and I.R. Kennedy. 1992. Distribution and Distribution of Endosufan and Related Cyclodienes in Sterile Aqueous systems: Implications for Studies on Biodegradation. J. Agric. Food Chem. 40:2315-2323.

Gupta, P. K. and R. C. Gupta. 1979. Pharmacology, toxicology and degradation of endosulfan. A review. Toxicology 13: 115 - 130.

Halsall, C.J., R. Bailey, G.A. Stern, L.A. Barre, P. Fellin, D.C.G. Muir, B. Rosenberg, F. Ya. Robinsky, E.Ya. Kononov, and B. Pastukhov. 1998. Multi-year observations of organohalogen pesticides in the Arctic atmosphere. Environmental Pollution. 102: 51-62.

Kammerbauer, J., and J. Moncada. 1998. Pesticide residue assessment in three selected agricultural production systems in the Choluteca River Basin of Honduras. Envir. Poll. 103:171-181.

Lehotay, S.J., J.A. Harman-Fetcho and L.L. McConnell. 1998. Agricultural Pesticide Residues in Oysters and Water from Two Chesapeake Bay Tributaries. Marine Pollution Bulletin. 37(1-2): 32-44.

LeNoir, J. S., et. al. "Summertime transport of current use pesticides from California's Central Valley to the Sierra Nevada Mountain Range, USA." Env. Toxicology and Chemistry, Vol. 18, No. 2, pp. 2715-2725

Leonard, A.W., R.V. Hyne, R.P. Lim and J.C. Chapman. 1999. Effect of endosulfan runoff from cotton fields on macroinvertebrates in the Namoi River. Ecotoxicol. Environ. Safety. 442(2): 125-134.

Liu, B., L.L. McConnell, and A. Torrents. 1998. Fate and Transport of Currently Used Pesticides in the Chesapeake Bay. Paper presented at the 18th Annual Meeting of SETAC. Charlotte, NC.

McConnell, L.L., J.S. Lenoir, S. Datta, and J.N. Seiber. 1998. Wet Deposition of Current-Use Pesticides in the Sierra Nevada Mountain Range, California, USA. Environ. Toxicol. Chem. 17(10): 1908-1916.

Miles, J.R.W. and P. Moye. 1979. Degradataion of Endosulfan and Its Metabolites by a Mixed Culture of Soil Microorganisms. Bull. Environ. Contam. Toxicol. 23: 13-19.

Montgomery, J.H. 1993. Agrichemicals desk reference: environmental data. Lewis Publishers. Chelsea, MI.

O'Brien, R.D. 1967. Insecticides: Action and Metabolism. pp. 145-146. Academic Press, Inc., New York.

Parkpian, P., P. Anurakpongsatorn, P. Pakkong, and W.H. Patrick, Jr. 1999. Adsorption, desorption and degradation of ˝-endosulfan in tropical soils of Thailand. J. Environ. Sci. Health - Part B Pestic., Food Contaminants, and Agric. Wastes. 33(3): 211-233.

Reyes, G.G., C.L. Villagrana, and G.L. Alvarez. 1999. Environmental conditions and pesticide pollution of two coastal ecosystems in the Gulf of California, Mexico. Ecotox. and Envir. Safety 44:280-286.

Rice, C.P., S.M. Chernyak, C.J. Hapeman, and S. Bilboulian. 1997. Air-Water distribution of the Endosulfan Isomers. J. Environ. Qual. 26(4): 1101-1106.

Rice, C.P., S.M. Chernya, and L.L. McConnell. 1997. Henry's Law Constants for Pesticides Measured as a Function of Temperature and Salinity. J. Agric. Food Chem. 45: 2291-2298.

Rice, C.P., C.B. Nochetto, and P. Zara. 1999. Volatilization of trifluralin, atrazine, metolachlor, chlorpyrifos, endosulfan I and endosulfan II from freshly tilled soil. Final Project Report. US EPA, Research Triangle Park, NC.

Royal Society of Chemistry. 1983. The Agrochemicals Handbook. Second Edition (Hartley, D and H. Kidd, eds.) Unwin brothers Limited, Old Woking, Surrey, United Kingdom.

Rudel, H. 1997. Volatilisation of pesticides from soil and plant surfaces. Chemosphere 35:143-152.

Schmidt, W.F. C.J. Hapeman, J.C. Fettinger, C.P. Rice, and S. Bilboulian. 1997. Structure and Asymmetry in the Isomeric Conversion of ˘- to ˝-Endosulfan. J. Agric. Food Chem. 45(4): 1023-1026.

Singh, N.C., T.P. Dasgupta, E.V. Roberts, and A. Mansingh. 1991. Dynamics of Pesticides in Tropical Conditions. 1. Kinetic Studies of Volatilization, Hydrolysis, and Photolysis of Dieldrin and ˝- and ˘-Endosulfan. J. Agric. Food Chem. 39: 575-579.

Singh, S., P. Dureja and S. Kumar. 2000. Biodegradation of ˝ and ˘ isomers of Endosulphan and Endosulphan Sulphate in Indian soils. J. Environ. Sci. Health. B35(3): 337-346.

Smith, G., C. H. L. Kennard, and K.G. Shields. 1977. Insecticides. XI. Crystal Structure of Endosulfan, ˝-6,7,8,9,10,10-hexachloro-1,5,5a,6,9,9a-hexahydro-endo-6,9-methano-2,3,4-benzodioxathiepin 3-oxide. Aust. J. Chem. 30: 911-916.

Soto, A.M., K.L. Chung and C. Sonnenschein. 1994. The Pesticides Endosulfan,Toxaphene and Dieldrin Have Estrogenic Effects on Human Estrogen-Sensitive Cells. Environ. Health Perspect. 102: 380-383.

Struger, J. 1998. Organophosphorus pesticides and endosulfan in surface waters of Niagara Fruit Belt, Ontario, Canada. Paper presented at the 18th Annual Meeting of SETAC. Charlotte, NC.

Wade, T.L., J.L. Sericano, P.R. Gardinali, G. Wolff, and L. Chambers. 1998. NOAA's 'mussel watch' project: current use organic compounds in bivalves. Marine Poll. Bull 37:20-26.

Zimmerman, L.R., E.M. Thurman, and K.C. Bastian. 2000. Detection of persistent organic pollutants in the Mississippi Delta using semipermeable membrane devices. Sci. of the Ttl. Envir. 248:169-179.

APPENDIX C: WATER EXPOSURE MODELING INPUTS AND OUTPUTS

The input and output files shown in this appendix are for the cotton scenario that was used in the drinking water resource assessment. The input and output files for the remaining crop scenarios modeled in the ecological exposure assessment are available from EFED upon request.

PRZM/EXAMS Input Parameters

Table C-1: PRZM/EXAMS environmental fate input parameters for endosulfan.

chemical	˜ - endosulfan	˘ - endosulfan
molecular weight	406.9	406.9
Solubility	530 . g/L	280 . g/L
vapor pressure	3.0×10^{-6} torr	7.2×10^{-7} torr
pH 7 hydrolysis half life	19 days	10.7 days
aqueous photolysis half life (near surface)	stable	stable
soil photolysis half life	stable	stable
aerobic soil metabolism half life	57 days (upper 90% c.i.)	208 days (upper 90% c.i.)
aerobic aquatic metabolism half life	114 days (2 x 57 day soil metabolism PRZM value)	416 days (2 x 208 day soil metabolism PRZM value)
anaerobic aquatic metabolism half life	286 days (2 x upper 90% c.i. of anaerobic soil study)	382 days (2 x upper 90% c.i. of anaerobic soil study)
soil organic carbon partitioning (Koc)	10600 L kg^{-1} (mean value)	13500 L kg^{-1} (mean value)
crop	cotton	cotton
application rate	70% of 1 lb a.i. acre	30% of 1 lb a.i. acre
number of applications	3	3
application method	aerial	aerial
application dates	1-Jun, 9-Jul, 16-Aug [a]	1-Jun, 9-Jul, 16-Aug [a]
spray efficiency	75%	75%
spray drift	5% of mass applied to 1 acre at each application time for tier 2; no drift for refined assessment	5% of mass applied to 1 acre at each application time for tier 2; no drift for refined assessment

[a] Application dates were taken from the registrant's PRZM simulations, which were included in a July 7, 1999 letter from AgrEvo. Label does not specify intervals.

PRZM Input Files For the Modeled Crops

NY apples
```
*** PRZM 3.1 Input Data File ***
*** NYAPPLE.INP,modified 3/17/00 ***
*** Mannings N value for sparse grass under trees ***
*** Original file used Sharky Clay loam; changed to Cabot silt loam; 3% of MLRA ***
endosulfan
Columbia Co, New York; MLRA 144B Apples, Crab Apples, Quince
***RECORD 3
   0.850   0.450        2  20.000        1        3
***RECORD 4
     9.7    10.4    11.8    13.1    14.3    14.8
***RECORD 5
    14.5    14.0    12.3    11.0     9.8     9.1
***RECORD 6
      4
***RECORD 7
***Note YYYY=010.0 for farm pond =172.8 for index reservoir
***Note XXXXX =354.0 for farm pond = 600.0 for index reservoir
    0.01    0.01     1.0   YYYYY     3.8        3   12.00   XXXXX
***RECORD 8
      1
***RECORD 9
      1    0.30    60.0  90.000        3  94  84  89    0.00    500.0
***RECORD 9A
      1        3
***RECORD 9B,C,D
0103 0111 0101
0.74 0.01 0.01
.015 .015 .015
***RECORD 10
     36
***RECORD 11
  010448  150548  151248        1
  010449  150549  151249        1
< Dates repeated yearly 1948-1983 >
  010482  150582  151282        1
  010483  150583  151283        1
***RECORD 12
ENDOSULFAN
***RECORD 13
     72        1        0
***RECORD 15
ENDOSULFAN
***RECORD 16
***Note: XXXX = 0.00 w/ spray drift buffer = 0.01 w/o
***Note application rates depend on whether labeled or typical rates are used
*** see Table 3 in text
  010548  0 2 0.00  1.68 0.99 XXXX
  110548  0 2 0.00  1.68 0.99 XXXX
  010549  0 2 0.00  1.68 0.99 XXXX
  110549  0 2 0.00  1.68 0.99 XXXX
< 2 yearly applications repeated on the same dates, 1948-1983 >
  010582  0 2 0.00  1.68 0.99 XXXX
  110582  0 2 0.00  1.68 0.99 XXXX
  010583  0 2 0.00  1.68 0.99 XXXX
  110583  0 2 0.00  1.68 0.99 XXXX
***RECORD 17
    0.0        3        0.0
***RECORD 18
    0.0      0.0      0.5
```

```
***RECORD 19
Cabot Silt loam; Hydrologic Group D;
***RECORD 20: SET KDFLAG TO CALCULATE KD FROM KOC
  100.00            0   0   1   0   0   0   0   0   0
***RECORD 26
     0.0    0.00    0.00
***RECORD 30
*** Note: XXXX= Koc alpha = 10600 =Koc beta= 13500
      4    XXXXX.
***record 33
      3
***RECORD 34,36,37*********************************
*** Note XXXX= alpha =.0122; beta =.0033
      1    20.0    1.10   0.288     0.0     0.0
           .XXXX   .XXXX    0.00
            0.2   0.288   0.108   6.961     0.0
***RECORD 34,36,37*********************************
      2    16.0    1.70   0.197     0.0     0.0
           .XXXX   .XXXX    0.00
            2.0   0.197   0.037   0.290     0.0
***RECORD 34,36,37*********************************
      3    64.0    1.90   0.151     0.0     0.0
           .XXXX   .XXXX    0.00
            2.0   0.151   0.041   0.174     0.0
***RECORD 40 *********************************
      0
              YEAR        5            YEAR        5            YEAR        5   1
      1
      1   -----
***RECORD 45
      1    YEAR
    RUNF    TSER
```

Mississippi Cotton
```
*** PRZM 3.1 Input data File, MSCOTTN1.inp***
*** Modified 7/9/99 ***
*** Location: Yazoo County, Mississippi; MLRA: O-134 ***
*** Weather: MET131.MET Jackson, MS ***
*** Manning's N: Assume fallow surface with residues not more than 1 ton/acre ***
*** See MSCOTTN1.wpd for scenario description and metadata ***
Chemical: endosulfan
Location: Mississippi; Crop: cotton;  MLRA: O-134
*** record 3
    0.76    0.15        0   17.00        1        1
***record 6
      4
***Note YYYY=010.0 for farm pond =172.8 for index reservoir
***Note XXXXX =354.0 for farm pond = 600.0 for index reservoir
    0.49    0.40    0.75    YYYY                4    6.00    XXXXX
***record 8
      3
***record 9
      1    0.20  125.00   98.00       3  99  93  92    0.00  120.00
      2    0.20  125.00   98.00       3  94  84  83    0.00  120.00
      3    0.20  125.00   98.00       3  99  83  83    0.00  120.00
      1        3
0101 2109 2209
0.63 0.16 0.18
0.02 0.02 0.02
      2        3
0105 0709 2209
0.16 0.13 0.13
```

```
0.02 0.02 0.02
      3         3
0105 0709 2209
0.16 0.13 0.09
0.02 0.02 0.02
***record 10
      20
***record 11
  01 564  07 964  220964        1
  01 565  07 965  220965        2
  01 566  07 966  220966        3
< Dates repeated in 3-year rotations, 1948-1983 >
  01 582  07 982  220982        1
  01 583  07 983  220983        2
Application schedule:
      60        1        0        0
Chemical:
***Note: XXXX = 0.00 w/ spray drift buffer = 0.05 w/o
***Note application rates depend on whether labeled or typical rates are used
*** see Table 3 in text
  010664  0 2 0.00  0.45 0.75 X.XX
  130664  0 2 0.00  0.45 0.75 X.XX
  250664  0 2 0.00  0.45 0.75 X.XX
  010665  0 2 0.00  0.45 0.75 X.XX
  130665  0 2 0.00  0.45 0.75 X.XX
  250665  0 2 0.00  0.45 0.75 X.XX
< 3 yearly applications repeated on the same dates, 1964-1983 >
  010682  0 2 0.00  0.45 0.75 X.XX
  130682  0 2 0.00  0.45 0.75 X.XX
  250682  0 2 0.00  0.45 0.75 X.XX
  010683  0 2 0.00  0.45 0.75 X.XX
  130683  0 2 0.00  0.45 0.75 X.XX
  250683  0 2 0.00  0.45 0.75 X.XX
***record 17
    0.00        3     0.00
***record 18
    0.00     0.00     0.50
Soil Series: Loring silt loam; Hydrogic Group C
***record 20: SET KDFLAG TO CALCULATE KD FROM KOC
  155.00    0.00    0   0   1   0   0   0   0   0    0
***record 26
    0.00     0.00    00.00
***RECORD 30: SET KOC TO 10600 ml/g FOR ENDO (ALPHA)
*** Note: XXXX= Koc alpha = 10600 =Koc beta= 13500
      4 XXXXX.
***record 33
      6
*** record 34
      1  13.00   1.400   0.385   0.000   0.000   0.000
*** record 36
*** Note XXXX= alpha =.0122; beta =.0033
            .XXXX    .XXXX     0.00
            0.100    0.385    0.151    2.180    213.3
      2  23.00   1.400   0.370   0.000   0.000   0.000
            .XXXX    .XXXX     0.00
            1.000    0.370    0.146    0.490     47.9
      3  33.00   1.400   0.370   0.000   0.000   0.000
            .XXXX    .XXXX     0.00
            1.000    0.370    0.146    0.160     15.7
      4  30.00   1.450   0.340   0.000   0.000   0.000
            .XXXX    .XXXX     0.00
            1.000    0.340    0.125    0.124     12.1
      5  23.00   1.490   0.335   0.000   0.000   0.000
```

```
        .XXXX    .XXXX    0.00
        1.000    0.335    0.137    0.070    0.7
     6  33.00    1.510    0.343    0.000    0.000    0.000
        .XXXX    .XXXX    0.00
        1.000    0.343    0.147    0.060    0.6
     0
   WATR    YEAR      10    PEST    YEAR      10    CONC    YEAR      10    1
     1
     1  -----
     7    DAY
   PRCP    TSER    0    0
   RUNF    TSER    0    0
   INFL    TSER    1    1
   ESLS    TSER    0    0    1.E3
   RFLX    TSER    0    0    1.E5
   EFLX    TSER    0    0    1.E5
   RZFX    TSER    0    0    1.E5
```

New York Grapes
***Chautauqua County has highest acreage of Grapes in NY (3rd highest state in US) ***
***Erie, PA Weather Station used - closest to county, Grapes with grass cover ***
***Soil Hornell, Hydrologic Group D ***
Office, Viticulture Specialist: pthroop@cce.cornell.edu; (716) 672-2191.
Assume poor grass coverage under vines and overland flow
Endosulfan
Hornell silt loam; MLRA L-100, Chautauqua County, New York, Grapes
***Note YYYY=010.0 for farm pond =172.8 for index reservoir
***Note XXXXX =354.0 for farm pond = 600.0 for index reservoir
```
   0.780    0.300      0    15.00      1      1
        4
   0.33    1.00    1.00    YYYYY    5.80      3    15.00    XXX.0
        1
        1    0.25    90.00    100.00      3    94    91    93    0.00    150.0
        1      3
0101 0106 0110
0.50 0.50 0.50
.023 .023 .023
     23
 310561  220861  151061        1
 310562  220862  151062        1
```
< Dates repeated yearly 1961-1983 >
```
 310582  220882  151082        1
 310583  220883  151083        1
```
Application Schedule:
```
     46        1        0        0
```
ENDOSULFAN
***Note: XXXX = 0.00 w/ spray drift buffer = 0.05 w/o
***Note application rates depend on whether labeled or typical rates are used
***see Table 3
```
  150561  0 2 0.00  1.68 0.75 XXXX
  250561  0 2 0.00  1.68 0.75 XXXX
  150562  0 2 0.00  1.68 0.75 XXXX
  250562  0 2 0.00  1.68 0.75 XXXX
```
< 2 yearly applications repeated on the same dates, 1961-1983 >
```
  150582  0 2 0.00  1.68 0.75 XXXX
  250582  0 2 0.00  1.68 0.75 XXXX
  150583  0 2 0.00  1.68 0.75 XXXX
  250583  0 2 0.00  1.68 0.75 XXXX
    0.0        3      0.0
    0.00    0.00    0.50
```
Hornell Silt Loam; Hydrologic Group D;
RECORD 20 *******SET KD FLAG HERE******************

```
   100.0            0   0   1   0   0   0   0   0   0
***RECORD 26
    0.0     0.0      0.0
***RECORD 30 ********SET KOC TO HERE*******************
*** Note: XXXX= Koc alpha = 10600 =Koc beta= 13500
      4 XXXXX.
***RECORD 33
      3
***RECORD 34,36,37***********************************
      1   18.00   1.400   0.322   0.000   0.000   0.00
          .XXXX   .XXXX    0.00
           0.1   0.322   0.162   1.740    0.00
***RECORD 34,36,37***********************************
      2   66.00   1.500   0.310   0.000   0.000   0.00
          .XXXX   .XXXX    0.00
           1.0   0.310   0.200   0.174    0.00
***RECORD 34,36,37***********************************
      3   16.00   1.950   0.260   0.000   0.000   0.00
          .XXXX   .XXXX    0.00
           1.0   0.260   0.190   0.116    0.00
***RECORD 40 *******************************
      0
            YEAR        5              YEAR        5           YEAR        5   1
      1
      1  -----
      6    YEAR
   PRCP    TCUM   0   0
   RUNF    TCUM   0   0
   ESLS    TCUM   0   0   1.0E3
   RFLX    TCUM   0   0   1.0E5
   EFLX    TCUM   0   0   1.0E5
   RZFX    TCUM   0   0   1.0E5


**Tennessee Lettuce**
***PRZM 3.1 Input:  Lettuce.inp
***Loc: N-130 Tennessee Lettuce Scenario
***Record 1
Endosulfan
***Record 2
Tennessee N-130
***Record 3
   0.700   0.500       0   30.00       1       1
***Record 6
      4
***Record 7
***Note YYYY=010.0 for farm pond =172.8 for index reservoir
***Note XXXXX =354.0 for farm pond = 600.0 for index reservoir
    0.32    0.14    1.00    YYYY            3    6.00    XXXXX
***Record 8
      1
***Record 9
      1    0.05   35.00   80.00       2  86  78  82    0.00   30.00
***Record 9a
      1       3
***Record 9b,c,d
0101 1206 2611
0.01 0.01 0.01
0.17 0.17 0.17
***Record 10
     36
***Record 11
```

```
   310348  220748  010848        1
   310349  220749  010849        1
< Dates repeated yearly 1948-1983 >
   310382  220782  010882        1
   310383  220783  010883        1
***Record 12
ENDOSULFAN
***Record 13
     72       1       0       0
***record 15
ENDOSULFAN
***Record 16
***Note: XXXX = 0.00 w/ spray drift buffer = 0.05 w/o
***Note application rates depend on whether labeled or typical rates are used
***see Table 3
  150548  0 2 0.00  0.78 0.75 X.XX
  250548  0 2 0.00  0.78 0.75 X.XX
  150549  0 2 0.00  0.78 0.75 X.XX
  250549  0 2 0.00  0.78 0.75 X.XX
< 2 yearly applications repeated on the same dates, 1948-1983 >
  150582  0 2 0.00  0.78 0.75 X.XX
  250582  0 2 0.00  0.78 0.75 X.XX
  150583  0 2 0.00  0.78 0.75 X.XX
  250583  0 2 0.00  0.78 0.75 X.XX
***Record 17
    0.0       2     0.0
***Record 18
    0.0     0.0     0.5
***Record 19
  Series: HIDALGO                 Txt: Sandy Clay Loam
***RECORD 20 *******SET KD FLAG HERE*****************
   150.0          0   0   1   0   0   0   0   0   0
***RECORD 26
    0.0     0.0     0.0
***RECORD 30 ********SET KOC TO HERE*****************
*** Note: XXXX= Koc alpha = 10600 =Koc beta= 13500
      4 XXXXXX
***RECORD 33
      3
***RECORD 34,36,37 **********************************
*** Note XXXX= alpha =.0122; beta =.0033
      1   45.00   1.350   0.340   0.000   0.000
            XXXXX   XXXXX    0.00
          0.50    0.340   0.220   0.580   2.842
***RECORD 34,36,37 **********************************
      2   30.00   1.200   0.334   0.000   0.000
            XXXXX   XXXXX    0.00
          1.00    0.334   0.214   0.116   0.568
***RECORD 34,36,37 **********************************
      3   75.00   1.250   0.353   0.000   0.000
            XXXXX   XXXXX    0.00
          5.00    0.353   0.233   0.058   0.284
***Record 40 ********************************************
      0
***Record 42
          YEAR        5            YEAR        5            YEAR        5   1
      6
      1  -----
      6    YEAR
   PRCP    TCUM   0   0
   RUNF    TCUM   0   0
   RFLX    TCUM   0   0   1.0E5
   EFLX    TCUM   0   0   1.0E5
```

```
   ESLS     TCUM    0    0    1.0E3
   RZFX     TCUM    0    0    1.0E5
```

GA Pecan
Based on mature trees located in the southern piedmont of Georgia
Georgia #2 state behind Texas; GA Counties of Mitchell and Dougherty
Mannings N value for sparse grass
ENDOSULFAN
Williston Loamy Sand; Hydrologic group C; MLRA: P-138
***RECORD 3
   0.740   0.150   0   20.00   1   1
***RECORD 6
        4
***RECORD 7
***Note YYYY=010.0 for farm pond =172.8 for index reservoir
***Note XXXXX =354.0 for farm pond = 600.0 for index reservoir
     0.10   1.00   1.00   YYYYY   3   6.00   XXXXX
***RECORD 8
        1
***RECORD 9
        1   0.10   45.00   80.00   3   91   85   88   0.00   900.0
***RECORD 9A
        1   3
***RECORD 9B,9C,9D
0101 0105 1009
0.50 0.50 0.50
.015 .015 .015
***RECORD 10
       36
***RECORD 11
   110548   210948   061048   1
   110549   210949   061049   1
< Dates repeated yearly 1948-1983 >
   110582   210982   061082   1
   110583   210983   061083   1
***RECORD 12
Appication Schedule:
***RECORD 13
       72   1   0   0
***RECORD 15
ENDOSULFAN
***RECORD 16
***Note: XXXX = 0.00 w/ spray drift buffer = 0.05 w/o
***Note application rates depend on whether labeled or typical rates are used
***see Table 3
   010648 0 2 0.00 1.68 0.99 XXXX
   110648 0 2 0.00 1.68 0.99 XXXX
   010649 0 2 0.00 1.68 0.99 XXXX
   110649 0 2 0.00 1.68 0.99 XXXX
< 2 yearly applications repeated on the same dates, 1948-1983 >
   010682 0 2 0.00 1.68 0.99 XXXX
   110682 0 2 0.00 1.68 0.99 XXXX
   010683 0 2 0.00 1.68 0.99 XXXX
   110683 0 2 0.00 1.68 0.99 XXXX
***RECORD 17
     0.0   3   0.0
***RECORD 18
     0.0   0.0   0.5
***RECORD 19
WILLISTON Loamy Sand, Hydrologic Group C
***RECORD 20
   100.00   0   0   1   0   0   0   0   0   0
```

```
***RECORD  26
     0.0      0.0      0.0
***RECORD 30: SET KOC TO 9780 ml/g FOR ENDO
*** Note: XXXX= Koc alpha = 10600 =Koc beta= 13500
      4 XXXXX.
***RECORD 33
      3
***RECORD 34,36,37********************************
*** Note XXXX= alpha =.0122; beta =.0033
      1  30.00   1.450   0.149   0.000   0.000   0.000
            XXXXX   XXXXX    0.00
             0.1   0.149   0.069   1.160    13.6
***RECORD 34,36,37********************************
      2  16.00   1.700   0.245   0.000   0.000   0.000
            XXXXX   XXXXX    0.00
             0.5   0.245   0.125   0.174    13.6
***RECORD 34,36,37********************************
      3  54.00   1.700   0.332   0.000   0.000   0.000
            XXXXX   XXXXX    0.00
             1.0   0.332   0.192   0.116    13.6
***RECORD 40*************************************
      0
   WATR    YEAR      10   PEST    YEAR      10   CONC    YEAR      10   1
      1
      1  -----
      7  DAY
   PRCP    TSER   0   0
   RUNF    TSER   0   0
   INFL    TSER   1   1
   ESLS    TSER   0   0   1.E3
   RFLX    TSER   0   0   1.E5
   EFLX    TSER   0   0   1.E5
   RZFX    TSER   0   0   1.E5


**Maine potato**
*** POTATO.INP Farm pond***
*** Assume 4% slope, conventional tillage with crop residue left ***
*** on the field after harvest ***
*** Manning's N value for planted across slope poor stand at ***
Endosulfan
Conant Silt Loam MLRA M-143, Arastook County, ME
***RECORD 3
   0.770   0.150       0   12.50       1       3
***RECORD 6
      4
***RECORD 7
***Note YYYY=010.0 for farm pond =172.8 for index reservoir
***Note XXXXX =354.0 for farm pond = 600.0 for index reservoir
    0.28    0.44    1.00   YYYYY            3    4.00   XXX.X
***RECORD 8
      1
***RECORD 9
      1   0.10   30.00   90.00       3  91  85  88    0.00    40.0
***RECORD 9A
      1       3
***RECORD 9B,C,D
0101 0105 0109
0.43 0.27 0.43
.018 .018 .018
***RECORD 10,11
     36
  050548  080948  180948         1
```

77

```
  050549  080949  180949        1
< Dates repeated yearly 1948-1983 >
  050582  080982  180982        1
  050583  080983  180983        1
***RECORD 12
Application Schedule:
***RECORD 13
      36       1       0        0
***RECORD 15
ALPHA ENDOSULFAN
***RECORD 16
***Note: XXXX = 0.00 w/ spray drift buffer = 0.05 w/o
***Note application rates depend on whether labeled or typical rates are used
***see Table 3
  150648  0 2 0.00  0.90 0.75 XXXX
  150649  0 2 0.00  0.90 0.75 XXXX
< 1 yearly application repeated on the same date, 1948-1983 >
  150682  0 2 0.00  0.90 0.75 XXXX
  150683  0 2 0.00  0.90 0.75 XXXX
***RECORD 17
    0.0       1     0.0
***RECORD 18
    0.0     0.0     0.5
***RECORD 19
Soil Series: Conant Silt Loam
***RECORD 20: SET KDFLAG TO CALCULATE KD FROM KOC
  100.00          0   0   1   0   0   0   0   0   0
***RECORD 26
    0.0    0.00    0.00
***RECORD 30: SET KOC TO 9780 ml/g FOR ENDO
*** Note: XXXX= Koc alpha = 10600 =Koc beta= 13500
      4 XXXXX.
***record 33
      4
***RECORD 34,36,37*************************************
      1   10.00   1.250   0.341   0.000   0.000   0.000
          XXXXX   XXXXX    0.00
          0.1   0.341   0.121   4.640    0.00
***RECORD 34,36,37*************************************
      2   16.00   1.250   0.341   0.000   0.000   0.000
          XXXXX   XXXXX    0.00
          1.0   0.341   0.121   4.640    0.00
***RECORD 34,36,37*************************************
      3   64.00   1.400   0.266   0.000   0.000   0.000
          XXXXX   XXXXX    0.00
          1.0   0.266   0.116   0.174    0.00
***RECORD 34,36,37*************************************
      4   10.00   1.600   0.261   0.000   0.000   0.000
          XXXXX   XXXXX    0.00
          1.0   0.261   0.111   0.116    0.00
***RECORD 40*********************************************
      0
***RECORD 42
   WATR    YEAR      10    PEST    YEAR      10    CONC    YEAR      10    1
      1
      1   -----
      7    DAY
   PRCP    TSER   0    0
   RUNF    TSER   0    0
   INFL    TSER   1    1
   ESLS    TSER   0    0    1.E3
   RFLX    TSER   0    0    1.E5
```

```
     EFLX      TSER    0    0    1.E5
     RZFX      TSER    0    0    1.E5
```

NC tobbacco
```
*** Conventional tillage with crop residue left on the field after harvest
*** Manning's N value for small grain, across slope, moderate stand
*** 6 percent slope
*** Wake county 3rd highest production county in NC behind
*** Johnston and Pitt Counties ***
Endosulfan
Norfolk Loamy Sand; MLRA P-133A, Wake County, North Carolina, Tobacco
***RECORD 3
    0.770   0.150       0   27.50       1       3
***RECORD 6
        4
***RECORD 7
***Note YYYY=010.0 for farm pond =172.8 for index reservoir
***Note XXXXX =354.0 for farm pond = 600.0 for index reservoir
    0.24    0.33    1.00    YYYY             3    6.00    XXXXX
***RECORD 8
        1
***RECORD 9
        1    0.20   45.00   80.00      3  86  78  82    0.00     75.0
***RECORD 9A
        1        3
***RECORD 9B,C,D
0101 0105 0109
0.41 0.41 0.41
.023 .023 .023
***RECORD 10
       36
***RECORD 11
   110448  060748  160748        1
   110449  060749  160749        1
< Dates repeated yearly 1948-1983 >
   110482  060782  160782        1
   110483  060783  160783        1
***RECORD 12
Application Schedule:
***RECORD 13
       36        1        0        0
***RECORD 15
ENDOSULFAN ALPHA
***RECORD 16
***Note: XXXX = 0.00 w/ spray drift buffer = 0.05 w/o
***Note application rates depend on whether labeled or typical rates are used
***see Table 3
   010648  0 2 0.00  1.01 0.75 XXXX
   010649  0 2 0.00  1.01 0.75 XXXX
< 1 yearly application repeated on the same date, 1948-1983 >
   010682  0 2 0.00  1.01 0.75 XXXX
   010683  0 2 0.00  1.01 0.75 XXXX
        0        0     0.0
        0        0     0.5
Norfolk Loamy Sand; Hydrologic Group B;
***RECORD 20 *******SET KD FLAG HERE*******************
   150.0           0   0   1   0   0   0   0   0   0
***RECORD 26
    0.0     0.0     0.0
***RECORD 30 *******SET KOC TO HERE*******************
*** Note: XXXX= Koc alpha = 10600 =Koc beta= 13500
        4 XXXXX.
```

```
***RECORD 33
     4
***RECORD 34,36,37*************************************
*** Note XXXX= alpha =.0122; beta =.0033
     1   10.00   1.550   0.199   0.000   0.000
             XXXXX   XXXXX    0.00
               0.1   0.199   0.089   0.290    0.00
***RECORD 34,36,37*************************************
     2   35.00   1.550   0.199   0.000   0.000
             XXXXX   XXXXX    0.00
               5.0   0.199   0.089   0.290    0.00
***RECORD 34,36,37*************************************
     3   55.00   1.300   0.406   0.000   0.000
             XXXXX   XXXXX    0.00
               5.0   0.406   0.206   0.116    0.00
***RECORD 34,36,37*************************************
     4   50.00   1.100   0.396   0.000   0.000
             XXXXX   XXXXX    0.00
               5.0   0.396   0.246   0.058    0.00
***RECORD 40
     0
             YEAR        5            YEAR        5           YEAR        5    1
         6
      11    -----
***       7    DAY
      1    YEAR
***    PRCP    TCUM   0   0
    RUNF    TCUM   0    0
***    INFL    TCUM   1   1
***    ESLS    TCUM   0   0   1.0E3
***    RFLX    TCUM   0   0   1.0E5
***    EFLX    TCUM   0   0   1.0E5
***    RZFX    TCUM   0   0   1.0E5


Florida tomato
*** PRZM 3 INPUT FILE FOR FLORIDA TOMATO (CLASS B/D SOIL)
*** Modified form PRZM2 file, 3/22/2000
*** HYDROLOGY PARAMETERS, Florida, High Exposure Scenario
*** METEOROLOGY FILE = MET156a.met
*** Manning's N values(Record 9D)taken from FL strawberry scenario (same as sparse
grass)
endosulfan
Florida, High Exposure Scenario
***RECORD 3
    0.78    0.15       0    20.0       1       1
***RECORD 6
     4
***RECORD 7
***Note YYYY=010.0 for farm pond =172.8 for index reservoir
***Note XXXXX =354.0 for farm pond = 600.0 for index reservoir
    0.03    0.20    1.00    YYYY               3    2.00    XXXXX
***RECORD 8
     1
***RECORD 9
     1    0.10   20.00    80.0       3  98  98  98    0.0    50.
***RECORD 9A
     1       3
***RECORD 9B,9C,9D
0104 1510 1201
0.25 0.25 0.25
.023 .015 .015
***RECORD 10
```

```
        36
***RECORD 11
  020248  210448  010548        1
  020249  210449  010549        1
< Dates repeated yearly 1948-1983 >
  020282  210482  010582        1
  020283  210483  010583        1
***RECORD 12
Application Schedule: 3@ 1 lb/acre
***RECORD 13
     108       1       0       0
***RECORD 15
ENDOSULFAN
***RECORD 16
***Note: XXXX = 0.00 w/ spray drift buffer = 0.05 w/o
***Note application rates depend on whether labeled or typical rates are used
***see Table 3
  010348  0 2 0.00  0.78 0.75 XXXX
  080348  0 2 0.00  0.78 0.75 XXXX
  150348  0 2 0.00  0.78 0.75 XXXX
  010349  0 2 0.00  0.78 0.75 XXXX
  080349  0 2 0.00  0.78 0.75 XXXX
  150349  0 2 0.00  0.78 0.75 XXXX
< 3 yearly applications repeated on the same dates, 1948-1983 >
  010382  0 2 0.00  0.78 0.75 XXXX
  080382  0 2 0.00  0.78 0.75 XXXX
  150382  0 2 0.00  0.78 0.75 XXXX
  010383  0 2 0.00  0.78 0.75 XXXX
  080383  0 2 0.00  0.78 0.75 XXXX
  150383  0 2 0.00  0.78 0.75 XXXX
***RECORD 17********************************
      0       3      0.0
***RECORD 18
    0.0    0.00     0.5
***RECORD 19
SOILS PARAMETERS  Felda,  Sand, 3977,  Class B/D
***RECORD 20 *******SET KD FLAG HERE*******************
  100.0          0   0   1   0   0   0   0   0   0
***RECORD 26
    0.0    0.0    0.0
***RECORD 30 ********SET KOC TO HERE********************
*** Note: XXXX= Koc alpha = 10600 =Koc beta= 13500
      4 XXXXX.
***RECORD 33
      3
***RECORD 34,36,37 ********************************
*** Note XXXX= alpha =.0122; beta =.0033
      1  10.00   1.550   0.060      0.      0.
            XXXXX   XXXXX   0.00
           0.10   0.085   0.035   0.580     0.0
***RECORD 34,36,37********************************
      2  72.00   1.600   0.133      0.      0.
            XXXXX   XXXXX   0.00
           1.00   0.183   0.083   0.174     0.0
***RECORD 34,36,37********************************
      3  18.00   1.650   0.033      0.      0.
            XXXXX   XXXXX   0.00
           3.00   0.043   0.023   0.116     0.0
***RECORD 40********************************
      0
   WATR   YEAR      10  PEST   YEAR      10  CONC   YEAR      10  1
      1
      1  -----
```

```
      7     DAY
PRCP    TSER   0    0
RUNF    TSER   0    0
INFL    TSER   1    1
ESLS    TSER   0    0    1.E3
RFLX    TSER   0    0    1.E5
EFLX    TSER   0    0    1.E5
RZFX    TSER   0    0    1.E5
```

Example of ˝-Endosulfan PRZM Output File

These results are normalized to an application rate of 1 lb/acre. To obtain the actual concentration for ˝-endosulfan, these values must be multiplied by the fraction of ˝-endosulfan in the application solution (i.e., 70 % for ˝-endosulfan).

WATER COLUMN DISSOLVED CONCENTRATION (PPB)

YEAR	PEAK	96 HOUR	21 DAY	60 DAY	90 DAY	YEARLY
1964	25.470	22.280	14.670	12.350	10.260	4.087
1965	22.020	19.330	12.370	7.283	5.822	2.787
1966	11.290	9.900	7.028	4.754	4.029	1.886
1967	11.350	9.955	7.506	5.415	4.901	2.285
1968	8.096	7.277	5.323	3.660	3.251	1.527
1969	12.390	10.820	6.911	4.297	3.522	1.457
1970	11.470	10.770	7.493	6.465	5.786	2.537
1971	10.790	9.488	5.963	4.503	4.489	2.134
1972	7.202	6.312	4.140	3.255	3.043	1.386
1973	8.165	7.501	5.141	3.589	3.406	1.636
1974	8.891	7.800	5.958	3.905	3.613	1.930
1975	15.470	13.510	10.190	7.546	6.109	2.630
1976	12.010	11.140	9.059	6.042	5.674	2.521
1977	8.247	7.247	4.951	4.320	3.870	2.055
1978	7.192	6.305	4.505	3.448	3.171	1.457
1979	26.180	23.500	16.470	11.810	10.090	4.146
1980	7.508	6.616	4.371	3.518	3.413	1.859
1981	9.946	8.702	5.976	4.507	4.069	1.746
1982	13.850	12.240	10.510	8.428	7.322	3.293
1983	9.089	7.982	5.192	3.996	3.598	2.016

SORTED FOR PLOTTING

PROB	PEAK	96 HOUR	21 DAY	60 DAY	90 DAY	YEARLY
.048	26.180	23.500	16.470	12.350	10.260	4.146
.095	25.470	22.280	14.670	11.810	10.090	4.087
.143	22.020	19.330	12.370	8.428	7.322	3.293
.190	15.470	13.510	10.510	7.546	6.109	2.787
.238	13.850	12.240	10.190	7.283	5.822	2.630
.286	12.390	11.140	9.059	6.465	5.786	2.537
.333	12.010	10.820	7.506	6.042	5.674	2.521
.381	11.470	10.770	7.493	5.415	4.901	2.285
.429	11.350	9.955	7.028	4.754	4.489	2.134
.476	11.290	9.900	6.911	4.507	4.069	2.055
.524	10.790	9.488	5.976	4.503	4.029	2.016
.571	9.946	8.702	5.963	4.320	3.870	1.930
.619	9.089	7.982	5.958	4.297	3.613	1.886
.667	8.891	7.800	5.323	3.996	3.598	1.859
.714	8.247	7.501	5.192	3.905	3.522	1.746
.762	8.165	7.277	5.141	3.660	3.413	1.636
.810	8.096	7.247	4.951	3.589	3.406	1.527
.857	7.508	6.616	4.505	3.518	3.251	1.457
.905	7.202	6.312	4.371	3.448	3.171	1.457
.952	7.192	6.305	4.140	3.255	3.043	1.386
1/10	**25.125**	21.985	14.440	11.472	9.813	**4.008**

MEAN OF ANNUAL VALUES =   2.269
STANDARD DEVIATION OF ANNUAL VALUES =   .804

```
UPPER 90% CONFIDENCE LIMIT ON MEAN =    2.538
```

```
EEC calculations:
Acute EEC   = (1-in-10 peak value)(fraction beta)(percent crop area factor)
            = (25.125 .g/L)(0.7)(0.2)              = 3.5

Chronic EEC = (1-in-10 annual value)(fraction beta)(percent crop area factor)
            = (4.008 .g/L)(0.7)(0.2)               = 0.56
```

Example of ˘-Endosulfan PRZM Output File

These results are normalized to an application rate of 1 lb/acre. To obtain the actual concentration for ˘-endosulfan, these values must be multiplied by the fraction of ˘-endosulfan in the application solution (i.e., 30 % for ˘-endosulfan).

WATER COLUMN DISSOLVED CONCENTRATION (PPB)

YEAR	PEAK	96 HOUR	21 DAY	60 DAY	90 DAY	YEARLY
1964	25.570	21.330	12.560	10.540	8.832	3.765
1965	30.870	25.760	14.410	7.533	5.830	2.896
1966	12.200	10.240	7.303	4.516	3.841	2.096
1967	12.430	10.430	7.205	4.998	4.608	2.644
1968	8.315	7.236	4.916	3.284	2.994	2.011
1969	14.100	11.760	6.645	3.910	3.185	1.579
1970	13.880	11.610	8.400	7.191	6.682	2.915
1971	15.630	13.100	7.175	4.609	4.494	2.880
1972	7.006	5.899	3.579	2.801	2.663	1.611
1973	8.190	7.310	4.710	3.381	3.095	2.155
1974	9.333	7.892	6.475	5.008	3.879	2.894
1975	19.110	15.950	10.940	7.192	5.862	2.963
1976	13.720	12.530	9.492	5.896	5.505	2.875
1977	8.663	7.335	4.722	3.988	3.619	2.809
1978	7.115	6.004	4.009	2.953	2.799	1.745
1979	29.110	25.020	16.270	11.080	9.673	4.960
1980	8.490	7.614	5.174	4.140	3.776	2.729
1981	10.890	9.136	6.666	4.544	3.936	1.986
1982	18.350	15.650	10.720	8.101	7.143	4.045
1983	9.328	7.880	5.283	4.142	3.583	3.044

SORTED FOR PLOTTING

PROB	PEAK	96 HOUR	21 DAY	60 DAY	90 DAY	YEARLY
.048	30.870	25.760	16.270	11.080	9.673	4.960
.095	29.110	25.020	14.410	10.540	8.832	4.045
.143	25.570	21.330	12.560	8.101	7.143	3.765
.190	19.110	15.950	10.940	7.533	6.682	3.044
.238	18.350	15.650	10.720	7.192	5.862	2.963
.286	15.630	13.100	9.492	7.191	5.830	2.915
.333	14.100	12.530	8.400	5.896	5.505	2.896
.381	13.880	11.760	7.303	5.008	4.608	2.894
.429	13.720	11.610	7.205	4.998	4.494	2.880
.476	12.430	10.430	7.175	4.609	3.936	2.875
.524	12.200	10.240	6.666	4.544	3.879	2.809
.571	10.890	9.136	6.645	4.516	3.841	2.729
.619	9.333	7.892	6.475	4.142	3.776	2.644
.667	9.328	7.880	5.283	4.140	3.619	2.155
.714	8.663	7.614	5.174	3.988	3.583	2.096
.762	8.490	7.335	4.916	3.910	3.185	2.011
.810	8.315	7.310	4.722	3.381	3.095	1.986
.857	8.190	7.236	4.710	3.284	2.994	1.745
.905	7.115	6.004	4.009	2.953	2.799	1.611
.952	7.006	5.899	3.579	2.801	2.663	1.579
1/10	**28.756**	24.651	14.225	10.296	8.663	**4.017**

MEAN OF ANNUAL VALUES =   2.730
STANDARD DEVIATION OF ANNUAL VALUES =   .841

```
UPPER 90% CONFIDENCE LIMIT ON MEAN =    3.012
```

EEC calculations:
Acute EEC   = (1-in-10 peak value)(fraction beta)(percent crop area factor)
            = (28.756 .g/L)(0.3)(0.2)   = 1.7

Chronic EEC = (1-in-10 annual value)(fraction beta)(percent crop area factor)
            = (4.017 .g/L)(0.3)(0.2)   = 0.24

APPENDIX D: CALCULATIONS FOR TERRESTRIAL EXPOSURE

Spreadsheet-based Terrestrial Exposure Values

A first order decay assumption is used to determine the concentration at each day after initial application based on the concentration resulting from the initial and additional applications. The decay is calculated from the first order rate equation:

$$\mathbf{C_T = C_i e^{-kT}}$$

or in log-transformed:

$$\mathbf{\ln (C_T/C_i) = -kT}$$

Where:

$\mathbf{C_T}$ = concentration at time T

$\mathbf{C_i}$ = concentration in parts per million (ppm) present initially (on day zero) on the surfaces. C_i is calculated based on Kanega and Fletcher by multiplying the application rate, in pounds active ingredient per acre, by 240 for short grass, 110 for tall grass, and 135 for broad-leaf plants/insects and 15 for seeds. Additional applications are converted from pounds active ingredient per acre to PPM on the plant surface and the addition mass added to the mass of the chemical still present on the surfaces on the day of application.

$\mathbf{k}$= degradation rate constant determined from studies of hydrolysis, photolysis, microbial degradation, etc. Since degradation rate is generally reported in terms of half-life, the rate constant is calculated from the input half-life (k = ln 2/T1/2) instead of being input directly. Choosing which process controls the degradation rate and which half-life to use in terrestrial exposure calculations is open for debate and should be done by a qualified scientist.

$\mathbf{T}$= time, in days, since the start of the simulation. The initial application is on day 0. The simulation is set to run for 365 days.

The program calculates concentration on each type of surface on a daily interval for one year. The maximum concentration during the year and the average concentration during the first 56 days are calculated.

APPENDIX E: ECOLOGICAL TOXICITY STUDIES

The following studies submitted by the registrant were used to develop an ecological toxicity assessment for endosulfan. The data consist of a combination of core studies that met the appropriate guideline requirements and supplemental studies that provided ancillary information.

Toxicity to Terrestrial Animals

Birds, Acute and Subacute

An acute oral toxicity study using the technical grade of the active ingredient (TGAI) is required to establish the toxicity of endosulfan to birds. The preferred test species is either mallard duck (a waterfowl) or bobwhite quail (an upland game bird). Since the LD_{50} for mallard ducks, i.e., 28 mg/kg, falls in the range of 10 to 50 mg/kg, endosulfan is categorized as highly toxic to avian species on an acute oral basis (**Table E-1**). The avian acute oral toxicity study requirement (Guideline 71-1) is fulfilled (MRID 137189, 136998,160000).

Table E-1. Summary of avian acute oral toxicity data for endosulfan.

Species	% ai	LD_{50} (mg/kg)	Toxicity Category	MRID No. Author/Year	Study Classification[1]
Northern bobwhite quail *(Colinus virginianus)*	97.2	42	highly toxic	137189/ Roberts and Phillips/1983	core
Mallard duck *(Anas platyrhynchos)*	97.2	28	highly toxic	136998/ Roberts and Phillips/1983	core
Mallard duck *(Anas platyrhynchos)*	96	33	highly toxic	160000/ Hudson et al./1984	core
Mallard duck *(Anas platyrhynchos)*	96	31.2	Highly toxic	160000/ Hudson et al./1984	core
Pheasant (Phasianus colchicus)	96	<160	Not categorized	160000/ Hudson et al./1984	core
Pheasant (Phasianus colchicus)	96	190	moderately toxic	160000/ Hudson et al./1984	core
Pheasant (Phasianus colchicus)	96	>320	Not categorized	160000/ Hudson et al./1984	core

[1] Core (study satisfies guideline). Supplemental (study is scientifically sound, but does not satisfy guideline)

Two subacute dietary studies using the TGAI are required to establish the toxicity of endosulfan to birds. The preferred test species are mallard duck and bobwhite quail. Since the LC_{50} for quail, *i.e.*, 805 ppm, falls in the range of 501 to 2,000 ppm, endosulfan is categorized as moderately toxic to avian species on a subacute dietary basis (**Table E-2**). The avian subacute dietary toxicity testing requirement (Guideline 71-2) is fulfilled (MRID 22923).

Table E-2. Summary of avian subacute dietary toxicity data on endosulfan.

Species	% ai	5-Day LC$_{50}$ (ppm)[1]	Toxicity Category	MRID No. Author/Year	Study Classification
Northern bobwhite quail *(Colinus virginianus)*	96	805	moderately toxic	22923/ Hill et al. /1975	core
Japanese quail	96	1,250	slightly toxic	22923	supplemental
Pheasant *(Phasianus colchicus)*	96	1,275	slightly toxic	22923	core
Mallard duck *(Anas platyrhynchos)*	96	1,053	slightly toxic	22923	core

[1] Test organisms observed an additional three days while on untreated feed.

Birds, Chronic

Avian reproduction studies using the TGAI are required for endosulfan because the following conditions are met: (1) birds may be subject to repeated or continuous exposure to the pesticide, especially preceding or during the breeding season, (2) the pesticide is stable in the environment to the extent that potentially toxic amounts may persist in animal feed, (3) the pesticide is stored or accumulated in plant or animal tissues, and/or, (4) information derived from mammalian reproduction studies indicates reproduction in terrestrial vertebrates may be adversely affected by the anticipated use of the product. The preferred test species are mallard duck and bobwhite quail. In chronic toxicity studies of technical grade endosulfan involving mallard ducks (MRID 402613-02), at 60 ppm there were treatment related effects upon reproductive parameters (reduction in the number of eggs laid and hatchability), adult body weight and feed consumption. The guideline (71-4) is fulfilled (MRID 403350-01, 403350-02, 146843, 402613-02).

Table E-3. Summary of avian reproductive toxicty studies using technical grade endosulfan.

Species/ Study Duration	% ai	NOEC/LOEC (ppm)	LOEC Endpoints	MRID No. Author/Year	Study Classification
Northern bobwhite quail *(Colinus virginianus)*	96	LOEC>60	LOEC>60	40335002	core
Mallard duck *(Anas platyrhynchos)*	96	LOEC>60	LOEC>60	40335001	core
Northern bobwhite quail *(Colinus virginianus)*	96	NOEC=60 LOEC= 120	120	402613-03	core
Mallard duck *(Anas platyrhynchos)*	tech		<30	146843	core
Mallard duck *(Anas platyrhynchos)*	96	NOEC=30 LOEC= 60	60	402613-02	core

Mammals, Acute and Chronic

Wild mammal testing is required on a case-by-case basis, depending on the results of lower tier laboratory mammalian studies, intended use pattern and pertinent environmental fate characteristics. In most cases, rat or mouse toxicity values obtained from the Agency's Health Effects Division (HED) substitute for wild mammal testing. Since acute toxicity estimates (Table 4) fall in the range of 10 to 50 mg/kg, endosulfan is classified as highly toxic on an acute exposure basis.

Table E-4. Summary of acute and chronic mammalian toxicity data based on acute oral toxicity study with rats, *Ratus norvegicus*, and a 2-generation reproduction study in rats using endosulfan.

Species/ Study Duration	% ai	Test Type	Toxicity Value	Affected Endpoints	MRID No.
laboratory rat (*Rattus norvegicus*)		Acute oral LD_{50}	10 mg/kg (female) 40 mg/kg (male)	mortality	00038307
laboratory rat		2-generation rat reproduction study	NOAEC = 15 ppm LOAEL = 75 ppm	decreased body weight	00148264

Insects

A honey bee acute contact study using the TGAI is required for endosulfan because its use will result in honey bee exposure. Since the LD_{50} falls in the range of 2 - 11 . g/bee, endosulfan is categorized as moderately toxic to honey bees on an acute contact basis (**Table E-5**). The acute contact toxicity study requirement (Guideline 141-1) is fulfilled (MRID 0001999, 5004151).

Table E-5. Summary of nontarget insect acute contact toxicity data on technical grade endosulfan.

Species	% ai	LD_{50} (µg/bee)	Toxicity Category	MRID No.	Study Classification
Honey bee (*Apis mellifera*)	tech	4.5	moderately toxic	0001999	core
Honey bee (*Apis mellifera*)	tech	7.1	moderately toxic	5004151	core

A honey bee toxicity of residues on foliage study using the typical end-use product is required for endosulfan because its use will result in honey bee exposure and the acute contact honey bee LD_{50} is less than 0.11 *ug*/bee. Based on two field studies, the toxicity of endosulfan was estimated to lie between an equivalent application rate of greater than 0.77 lbs per acre and less than 4.9 lbs per acre (Table E-6) for two separate formulations of endosulfan: an emulsifiable concentrate containing 35% a.i. and a formulation containing 17.5% a.i.. The guideline (141-2) is fulfilled (MRID 5004151, 05050025, 05012881).

Table E-6. Summary of residue on foliage toxicity studies for honey bees using endosulfan

Guideline	Formulation % a.i.	Toxicity ppm	MRID/Author/ year	Classification[1]
141-1 (honey bee)	tech	LD_{50} = 6.9 lba	05004151/ Stevenson/ 1968	core

Table E-6. Summary of residue on foliage toxicity studies for honey bees using endosulfan

Guideline	Formulation % a.i.	Toxicity ppm	MRID/Author/ year	Classification[1]
141-2 (honey bee)	35 EC	$_{LC50}$ > 0.77 lba	05050025/?	core
141-2 (honey bee)	17.5	LD_{50} < 4.9 lba	05012881/ Gorecki/ 1983	core

Toxicity to Freshwater Aquatic Animals

Freshwater Fish, Acute

Two freshwater fish toxicity studies using the TGAI are required to establish the toxicity of endosulfan to fish. The preferred test species are rainbow trout (a coldwater fish) and bluegill sunfish (a warmwater fish). Rainbow trout were the most sensitive (LC_{50} = 0.37 . g/L) species tested (**Table E-7**). Since the LC_{50} value was less than 0.1 mg/L, endosulfan is categorized as very highly toxic to freshwater fish on an acute exposure basis. The freshwater fish acute toxicity testing requirement (Guideline 72-1) is fulfilled (MRID 38806, 40094602, 40098001, 136999, 05008271).

Table E-7. Summary of freshwater fish acute toxicity data for endosulfan.

Species/ Flow-through or Static	% ai	96-hour LC_{50} (. g/L)	Toxicity Category	MRID No. Author/Year	Study Classification
Bluegill sunfish (*Lepomis macrochirus*)	96	2.08	very highly toxic	BA007903/EPA 1976/	supplemental
Bluegill sunfish (*Lepomis macrochirus*)	100	1.7	very highly toxic	38806	core
Bluegill sunfish (*Lepomis macrochirus*)	96.6	3.3	very highly toxic	05014941/ Pickering&Henderson/ 1966	supplemental
Bluegill sunfish (*Lepomis macrochirus*)	96	1.2	very highly toxic	40094602/ Johnson&Finley / 1980	core
Rainbow trout (*Oncorhynchus mykiss*) static	tech	1.5	very highly toxic	05003107/ Macek et al./ 1969	supplemental
Rainbow trout (*Oncorhynchus mykiss*) static	96	1.1	very highly toxic	40098001 Mayer&Ellerisieck / 1986	core
Rainbow trout (*Oncorhynchus mykiss*) static	95.9	0.83	very highly toxic	136999	core
Rainbow trout (*Oncorhynchus mykiss*) static	96	0.37	very highly toxic	BA007902 EPA / 1976	supplemental
Channel catfish (*Ictalurus nebulosus*)	96	1.5	very highly toxic	40094602 Johnson&Finley / 1980	core
Flathead catfish (*Pylodictis olivarius*)	96	1.5	very highly toxic	40094602 Johnson&Finley / 1980	core

Table E-7. Summary of freshwater fish acute toxicity data for endosulfan.

Species/ Flow-through or Static	% ai	96-hour LC_{50} (. g/L)	Toxicity Category	MRID No. Author/Year	Study Classification
Fathead minnow	96	1.5	Very highly toxic	Mayer & Ellersieck 1986	core
Flathead minnow (*Pimephales ptomelas*)	99	0.86	very highly toxic	05008271 Macek *et al.* / 1976	core

The acute toxicity of endosulfan to freshwater fish was tested using technical end product. There was considerable variability for LC_{50} values within formulations tested; toxicity estimates ranged from 0.47 . g/L to 2.7 . g/L for the 50 WP and 33.7% formulations, respectively (**Table E-8**). Similar to the results on technical grade active ingredient, rainbow trout were the most sensitive species tested using technical endproduct. Of the formulated products tested, the 4% formulation was the least toxic with an LC_{50} estimate of 28 . g/L. Based on the test results, the formulation of endosulfan is classified as being very highly toxic to freshwater fish species. The freshwater fish acute toxicity testing requirement using technical endproduct (Guideline 72-1) is fulfilled (MRID 00128655, BA007902, 250401A).

Table E-8. Summary of freshwater fish acute toxicity using endosulfan technical end product.

Species/ Flow-through or Static	% ai	96-hour LC_{50} (. g/L)	Toxicity Category	MRID No. Author/Year	Study Classification
Bluegill sunfish (*Lepomis macrochirus*)	33.7	5.6	very highly toxic	00128656/ Kinter& Forbis/1983	supplemental
Bluegill sunfish (*Lepomis macrochirus*)	50WP	3.9	very highly toxic	00128655/ Kinter& Forbis/1983	core
Rainbow trout (*Oncorhynchus mykiss*) static	50WP	0.47	very highly toxic	BA007902/EPA 1976	core
Rainbow trout (*Oncorhynchus mykiss*) static	50WP	2.3	very highly toxic	250401A/?/?	core
Rainbow trout (*Oncorhynchus mykiss*) static	33.7	2.7	very highly toxic	00128655/Kinter& Forbis/1983	supplemental
Carp	35	0.9	very highly toxic	05004792/Basak& Korar/1977	supplemental
Rainbow trout (*Oncorhynchus mykiss*) static	4	28	very highly toxic	0033020/Ludeman 1972	supplemental

Freshwater Fish, Chronic

An estimate of the chronic toxicity of technical grade endosulfan to freshwater fish was obtained using life cycle testing with the fathead minnows (*Pimephales promelas*) (**Table E-9**). The estimated lowest observed effect concentration was 0.4 . g/L. Reduced survival and mean total length of F_1 fathead minnows were the affected endpoints. Based on the acute to chronic ratio (LC50/NOEC = 1.5/0.2) the

NOEC for the most sensitive species, *i.e.*, rainbow trout, is predicted to 0.11 . g/L. The chronic toxicity testing requirement for freshwater fish (Guideline 72-5) is fulfilled (MRID 05008271).

Table E-9. Freshwater fish life-cycle toxicity under flow-through conditions

Species/ Study Duration	% ai	NOEC/LOEC . g/L	MATC[1] . g/L	Endpoints Affected	MRID Author/Year	Study Classification
Fathead minnow *(Pimephales promelas)*	99	NOEC = 0.2 LOEC= 0.4	0.28	Reduced survival and growth	05008271/ Macek et al./1976	Core
Rainbow trout *(Oncorhynchus mykiss)*		NOEC = 0.11[2]	--	--	--	--

[1] defined as the geometric mean of the NOEC and LOEC.
[2] NOEC for rainbow trout estimated using acute to chronic ratio for fathead minnow (1.5/0.2)

Freshwater Invertebrates, Acute

A freshwater aquatic invertebrate toxicity test using the TGAI is required to establish the toxicity of endosulfan to aquatic invertebrates. The preferred test species is *Daphnia magna*. Based on the available data (**Table E-10**), the estimated EC_{50} for technical grade endosulfan was 166 . g/L using daphnia and 6 . g/L for scuds (*Gammurus lacustris*). Scuds are consider to be moderately sensitive indicators of aquatic pollution and in this case proved to be a much more sensitive indicator of endosulfan toxicity than water fleas. Since the EC_{50} was less than 100 . g/L, endosulfan is categorized as being very highly toxic to aquatic invertebrates on an acute exposure basis. The freshwater invertebrate acute toxicity testing requirement (Guideline 72-2) is fulfilled (MRID 5008271, 400980-01, 400946-02).

Table E-10. Freshwater invertebrate acute toxicity using endosulfan.

Species	% ai	48-hour EC_{50} (. g/L)	Toxicity Category	MRID No. Author/Year	Study Classification
Waterflea *(Daphnia magna)*	99	166	very highly toxic	5008271 Macek et al. 1976	core
scud *(Gammurus lacustris)*	96	6	very highly toxic	40098001 Mayer& Ellersieck / 1986	core
scud *(G. lacustris)*	96	5.8	very highly toxic	40094602/ Johnson& Finley/ 1980	core

Acute toxicity (48-hr) data on the transient soil degradate of endosulfan, endosulfan diol, were submitted under FIFRA Section 6(a)(2). The results of this study (not reviewed by EPA) show an EC_{50} value of 0.58 mg/L and a NOEC value of 0.1 mg/L for the water flee. Based on these data, endosulfan diol is categorized as highly toxic to freshwater invertebrates.

Freshwater Invertebrate, Chronic

A freshwater aquatic invertebrate life-cycle test using the TGAI is required for endosulfan since the end-use product is expected to be transported to water from the intended use site, and the acute EC_{50} is less than 1 mg/L. The preferred test species is *Daphnia magna*. The lowest observed effect

concentration in daphnia (*Daphnia magna*) exposed to technical grade endosulfan was less than 7 . g/L (**Table E-11**). The study examined the effects of endosulfan on three consecutive generations of daphnids and noted that the poor survival of third generation daphnids in the control and the lowest treatment group, *i.e.*, 2.7 . g/L precluded drawing valid conclusions about the cumulative effects of exposure. It is noteworthy that the LOEC estimate for daphnids is equivalent to the acute toxicity estimate (6 . g/L) for scuds and does not provide a meaningful estimate of the chronic toxicity for freshwater invertebrates. Regression analysis of the 50-day survival data suggests that, the NOEC could be estimated at 2.0 . g/L Although the study (MRID 5008271) was initially classified as core, the study fails to provide an estimate of the NOEC and has been reclassified as supplemental. However, assuming the estimated NOEC of 2.0 . g/L is an accurate estimate of the NOEC for daphnids, then the acute to chronic ratio for daphnids (LC_{50}/NOEC: 166/2) could be used to predict the NOEC for the most sensitive species, *i.e.*, scuds. The result of this calculation is a predicted NOEC of 0.07 . g/L for scuds. The chronic invertebrate toxicity testing requirement (Guideline 72-4) is not fulfilled.

Table E-11. Freshwater aquatic invertebrate life-cycle toxicity using endosulfan.

Species	% ai	21-day NOEC/LOEC (. g/L)	MATC[1] (mg/L)	Endpoints Affected	MRID No. Author/Year	Study Classification
Waterflea (*Daphnia magna*)	99	NOEC = 2[2] LOEC<7	--	reduced survival	5008271/Macek et al./1976	core
Scud (*Gammurus lacustris*)	--	NOEC = 0.07[3]	--	--	--	--

[1] defined as the geometric mean of the NOEC and LOEC.
[2] predicted through regression analysis of survival data (log survival) = 5.643 - 1.0427(log concentration)
[3] predicted based on acute to chronic ratio for daphnids (EC_{50}/NOEC = 166/2)

Toxicity to Estuarine and Marine Animals

Estuarine and Marine Fish, Acute

Acute toxicity testing with estuarine/marine fish using the TGAI is required for endosulfan because the end-use product is expected to reach this environment because of its use in coastal counties. The preferred test species is sheepshead minnow. Acute toxicity estimates for marine/estuarine fish ranged from 0.1 . g/L to 0.32 . g/L (**Table E-12**); striped bass (*Morone saxatilis*) were the most sensitive ($LC_{50} = 0.1$. g/L) species tested. Based on these data, endosulfan is categorized as very highly toxic to marine/estuarine fish following an acute exposure. The acute toxicity testing requirement using estuarine/marine fish (Guideline 72-3) is fulfilled.(MRID 40228401).

Table E-12 . Summary of estuarine/marine fish acute toxicity studies of endosulfan.

Species/Static or Flow-through	% ai	96-hour LC_{50} (. g/L)	Toxicity Category	MRID No. Author/Year	Study Classification
Striped Bass (*Morone saxatilis*)	---	<1000	----	05000819/Korn& Earnest/1974	supplemental
Striped Bass (*Morone saxatilis*)	96	0.1	very highly toxic	00001328/Earnest/ 1970	supplemental

Table E-12 . Summary of estuarine/marine fish acute toxicity studies of endosulfan.

Species/Static or Flow-through	% ai	96-hour LC_{50} (. g/L)	Toxicity Category	MRID No. Author/Year	Study Classification
Striped Mullet (*Mugil cephalis*)	96	0.32	very highly toxic	40228401/Mayer 1986	supplemental
Striped Mullet (*Mugil cephalis*)	96	0.38	very highly toxic	40228401/Mayer 1986	core
Pinfish (*Lagodon rhomboides*)	96	0.3	very highly toxic	40228401/Mayer 1986	supplemental
Spot (*Leiostomus xanthurus*)	48	0.32	very highly toxic	40228401/Mayer 1986	supplemental

Estuarine and Marine Fish, Chronic

An estuarine/marine fish early life-stage toxicity test using the TGAI is required for endosulfan because the end-use product is expected to be transported to this environment from the intended use site and the aquatic acute LC_{50} is less than 1 mg/L. The preferred test species is sheepshead minnow. At the time of this review, no data were available to assess the chronic toxicity of endosulfan to estuarine/marine fish. Therefore, the chronic toxicity data requirement for estuarine/marine fish (Guideline 72-4) is not fulfilled. However, to estimate an NOEC for marine fish, the acute to chronic ratio for the freshwater fathead minnow (1.5/0.2) was used; based on the most sensitive marine species tested, i.e., striped bass ($LC_{50} = 0.1$. g/L) the estimated NOEC is 0.01 . g/L.

Estuarine and Marine Invertebrates, Acute

Acute toxicity testing with estuarine/marine invertebrates using the TGAI is required for endosulfan because the end-use product is expected to reach this environment because of its use in coastal counties. The preferred test species are mysid shrimp and eastern oyster. There was considerable variability in toxicity estimates for estuarine/marine invertebrates exposed to technical grade endosulfan; each of the EC_{50} estimates of oysters differed by at least an order of magnitude. Estimated EC_{50} values ranged from 0.45 . g/L to 460 . g/L and represented a difference of three orders of magnitude (**Table E-13**). Based on the most conservative estimate ($EC_{50} = 0.45$. g/L) for Eastern oysters, endosulfan is classified as very highly toxic to marine invertebrates. The estuarine/marine acute toxicity testing requirement (Guidelines 72-3b and 72-3c) is fulfilled (MRID 402284-01, 128688).

Table E-13. Summary of acute estuarine/marine invertebrate toxicity data for endosulfan.

Species/Static or Flow-through	% ai.	96-hour EC_{50} (. g/L))	Toxicity Category	MRID No. Author/Year	Study Classification
Eastern oyster (shell deposition or embryo-larvae) (*Crassostrea virginica*)	96	460	highly toxic	40228401/Mayer 1986	supplemental
Eastern oyster (shell deposition or embryo-larvae) (*Crassostrea virginica*)	96	0.45	very highly toxic	128688/Boeri& Ward/1983	core

Table E-13. Summary of acute estuarine/marine invertebrate toxicity data for endosulfan.

Species/Static or Flow-through	% ai.	96-hour EC$_{50}$ (. g/L))	Toxicity Category	MRID No. Author/Year	Study Classification
Eastern oyster (shell deposition or embryo-larvae) (*Crassostrea virginica*)	96	42	very highly toxic	40228401/Mayer 1986	core
Grass shrimp	96	1.3	very highly toxic	40228401/Mayer 1986	supplemental
Blue crab	96	19	very highly toxic	40228401/Mayer 1986	supplemental
Fiddler crab	96	790	highly toxic	128688/Boeri& Ward/1983	core

Acute toxicity testing using technical endproduct (48% a.i.) resulted in a 96-hr toxicity estimate of 0.24 . g/L (**Table E-14**). Based on these data, technical endproduct is categorized as very highly toxic to estuarine/marine invertebrates.

Table E-14. Estuarine/Marine Invertebrate Acute Toxicity-Technical end product of Endosulfan

Species	% ai.	96-hour LC$_{50}$ (. g/L)	Toxicity Category	MRID No. Author/Year	Study Classification
Brown Shrimp	48	0.24	very highly toxic	402284-01 Mayer/ 1986	supplemental

Estuarine and Marine Invertebrate, Chronic

An estuarine/marine invertebrate life-cycle toxicity test using the TGAI is required for endosulfan because the end-use product may be applied directly to the estuarine/marine environment or is expected to be transported to this environment from the intended use site, and the following conditions are met: (1) the pesticide is intended for use such that its presence in water is likely to be continuous or recurrent regardless of toxicity, (2) any aquatic acute LC$_{50}$ or EC$_{50}$ is less than 1 mg/L, (3) the EEC in water is equal to or greater than 0.01 of any acute LC$_{50}$ or EC$_{50}$ value, or, (4) the actual or estimated environmental concentration in water resulting from use is less than 0.01 of any acute LC$_{50}$ or EC$_{50}$ value and any of the following conditions exist: studies of other organisms indicate the reproductive physiology of fish and/or invertebrates may be affected, physicochemical properties indicate cumulative effects, or the pesticide is persistent in water (*e.g.*, half-life greater than 4 days). The preferred test species is mysid shrimp. The results of the test are reported below: Since the chronic toxicity test with mussels failed to provide an NOEC, the freshwater invertebrate acute to chronic ratio for daphnids (166/2) was used to predict the NOEC for the most sensitive marine invertebrate tested, i.e., Eastern oyster (EC$_{50}$ = 0.45 . g/L); thus, the estimated NOEC for Eastern oysters is 0.05 . g/L.

Table E-16: Chronic toxicity of endosulfan to estuarine/marine organisms.

Species/(Static Renewal or Flow-through)	% ai	21-day NOEC/LOEC . g/L	Endpoints Affected	MRID No. Author/Year	Study Classification
Mussel	NR	LOEC<0.5	--	05000047	supplemental

Eastern oyster	0.96	NOEC[1] = 0.05	--	128688/Boeri& Ward/1983	--

[1] NOEC predicted using freshwater daphnid acute to chronic ratio (166/2) applied to acute toxicity for Eastern oyster (EC$_{50}$ = 0.45 . g/L)

Chronic toxicity data were provided through a life cycle study conducted on mussels; the estimated LOEC was less than 0.5 ppb. Similar to studies involving fish, the chronic toxicity estimate was not definitive and proved to be higher than the acute toxicity estimate. In this case, the lower-end estimate for an acute EC$_{50}$ was 0.45 ppb and the LOEC was estimated to be 0.5 ppb. Thus, it is likely that the LOEC was considerably less than 0.5 ppm.. The guideline (72-4) is not fulfilled.

Toxicity to Plants

Terrestrial

Terrestrial plant testing (seedling emergence and vegetative vigor) is required for herbicides that have terrestrial non-residential outdoor use patterns and that may move off the application site through volatilization (vapor pressure >1.0 x 10^{-5}mm Hg at 25°C) or drift (aerial or irrigation) and/or that may have endangered or threatened plant species associated with the application site.

Currently, terrestrial plant testing is not required for pesticides other than herbicides except on a case-by-case basis (*e.g.*, labeling bears phytotoxicity warnings incident data or literature that demonstrate phytotoxicity).

Suitability of Ecotoxicity Data Submissions

Table E-17 summarizes the 206 studies submitted for consideration that were classified as acceptable (22%) and having provided useful information toward fulfilling the required guidelines. The remainder (78%) of the studies that did not pass an initial data screen are listed in **Table E-18**; data discrepancies are also listed. Many studies had been conducted prior to current Pesticide Assessment Guidelines; thus, their methodology could not be expected to conform entirely with present-day requirements. Although ecological effects were documented over a broad range of concentrations, toxicity estimates for species assembledges, *e.g.* freshwater fish, were tightly clustered and thus consistent.

Appendix Table E-17. Additional studies, classified as acceptable, that were submitted to support the reregistration of Endosulfan

Number	Reference	Year	Access Number
1	Atkins and Anderson	1969	00001999
2	Attri and Sharm	1969	05004597
3	Bartlett	1964	05004148
4	Bartlett	1963	05003978
5	Bartlett	1966	05005640
6	Beaver et al.	1987	40261302
7	Beavers et al.	1989	40261303

Appendix Table E-17. Additional studies, classified as acceptable, that were submitted to support the reregistration of Endosulfan

Number	Reference	Year	Access Number
8	Boeri and Ward	1983	128688
9	Buccafusco and Sleight	1976	BA007912
10	Clinch	1967	05008936
11	Clinch	1969	05002083
12	Colburn	1971	05004007
13	Coutin and Coulon	1969	05005993
14	Croft and Nelson	1972	05009345
15	Davies and McIaren	1977	05004003
16	Earnest	1970	00001328
17	Fischer	1983	--
18	Gorecki	1983	05012881
19	Harris and Svec	1969	05010080
20	Johansen	1972	05000837
21	Joshi and Sharmon	1973	05010085
22	Kinter and Forbis	0983	00128656
23	Kinter and Forbis	1983	00128655
24	Kinter and Forbis	1983	00128656
25	Kirknel	1975	05013237
26	Klostermeyer	1968	00003883
27	Kundu and Sharma	1974	05004542
28	Ludeman	1972	33020
29	Macek et al.	1976	05008271
30	Needham and Stevenson	1972	05004447
31	Okada	1970	05013090
32	Palmer-Jones and Forester	1958	05004413
33	Palmer-Jones et al.	1959	05004414
34	Palmer-Jones and Forester	1963	05004412
35	Palmer-Jones et al.	1959	05004794
36	Roberts and Phillips	1983	136998
37	Roberts and Phillips	1983	137189

Appendix Table E-17. Additional studies, classified as acceptable, that were submitted to support the reregistration of Endosulfan

Number	Reference	Year	Access Number
38	Roberts et al.	1985	146843
39	Schimmel et al.	1976	05005824
40	Searle	1964	05006416
41	Searle	1965	05005572
42	Singh et al.	1974	05003360
43	Stevenson	1968	05004151
44	Stevenson	1978	05001991
45	Tasei et al.	1972	05013358
46	Testia and Tiwari	1972	05013372
47	U.S. EPA	1976	BA007901

Appendix Table E-18. Additional studies that were submitted to support the reregistration of Endosulfan but did not pass initial screen. Data discrepancies responsible for rejection are listed.

Number	Reference	Year	Access Number	Discrepancy
1	Abreu et al.	1975	05014638	exotic species[1]
2	Alabaster	1969	05002896	formulation missing[13]
3	Ali et al.	1973	05019782	unreadable[2]
4	Amminikutty	1977	05003131	exotic species[1]
5	Amminikutty	1977	--	exotic species[1]
6	Anderson et al.	1962	05003871	secondary data[3]
7	Anon.	1968	00004409	secondary data[3]
8	Anon.	1971	05010470	fate study[4]
9	Arnold et al.	1973	--	methods paper[10]
10	Arora et al.	--	05003743	nonguideline[5]
11	Arzone	1975	05007035	secondary data[3]
12	Bartlett	1964	--	nonguideline[5]
13	Bartlett	1968	05009955	unreadable[2]
14	Basak and Korar	1976	--	not reviewed
15	Basak and Korar	1977	05004792	nonguideline[5]
16	Beran	1962	05011240	secondary data[3]
17	Binder	1969	05002082	newspaper article[3]
18	Bournoville and Tasei	1977	05006362	secondary data[3]
19	Brettell and Burgess	1973	05014828	no formulation[7]
20	Brueggemann et al.	1976	05014607	nonapplicable[6]
21	Butler et al.	1978	05007483	nonapplicable[6]
22	Celli	1974	05009720	secondary data[3]
23	Chalfant	1978	05013293	nonapplicable[6]
24	Claeys	1975	--	nonguideline[5]
26	Conti	1976	05009415	no endosulfan[8]
27	Croft and Brown	1975	--	secondary data[3]
28	Dalela et al.	1978	05011396	not reviewed
29	Dalela et al.	1978	05003496	exotic species[1]
30	Dalela et al.	1978	05003504	exotic species[1]
31	Davis and Wedemeyer	1971	05003996	no raw data[3]
32	Davis and Wedemeyer	1971	5003020	no raw data[3]

Appendix Table E-18. Additional studies that were submitted to support the reregistration of Endosulfan but did not pass initial screen. Data discrepancies responsible for rejection are listed.

Number	Reference	Year	Access Number	Discrepancy
33	Dunachie and Fletcher	1969	05005055	nonguideline[5]
34	Dustan	1965	--	nonguideline[5]
35	Dyck and Orlido	1977	0500740	exotic species[1]
36	Edwards and Hodgson	1973	05009430	exotic species[1]
37	Eichner	1973	05011225	no application rate[13]
38	Elsey	1976	05010420	unreadable[2]
39	Elzorgani et al.	1979	05004981	exotic species[1]/no endosulfan[8]
40	Engel	1959	05013910	secondary data[3]
41	Findlay	1970	05003994	exotic species[1]
42	Glofke	1976	05010079	methods development[10]
43	Goerke et al.	1979	05008230	nonguideline[5]
44	Gorbach	--	05012881	secondary data[3]
45	Greichus et al.	1978	05003116	nonguideline[5]
46	Grimm and Hoppe	1972	05006068	nonguideline[5]
47	Gupta	1976	--	nonguideline[5]
48	Gupta and Chandra	1975	--	nonguideline[5]
49	Hameed et al.	1973	05004909	insufficient data[11]
50	Hamilton and Altia	1976	05008939	insufficient data[11]
51	Hansen and Goodman	--	--	no raw data[3]
52	Haragsimova	1962	05010080	insufficient data[11]
53	Henderson et al.	1959	--	no endosulfan[8]
54	Hoyt	1969	--	mixture of compounds[12]
55	Hudson et al.	1972	05003462	insufficient data[11]
56	Hunt	1970	05004358	nonguideline[5]
57	Iren	1968	05015995	insufficient data[11]
58	Johansen	1960	--	nonguideline[5]
59	Jones	1975	05004539	nonguideline[5]
60	Kader	1976	05003954	nonguideline[5]
61	Kader	1976	05015005	nonguideline[5]
62	Kapil et al.	1972	05003722	exotic species[1]
63	Kapil and Lamba	1974	05003721	exotic species[1]

Appendix Table E-18. Additional studies that were submitted to support the reregistration of Endosulfan but did not pass initial screen. Data discrepancies responsible for rejection are listed.

Number	Reference	Year	Access Number	Discrepancy
64	Kinter and Forbis **S**	1983	--	nonguideline[5]
65	Klapon and Lewis	1979	05019675	insufficient data[11]
66	Klingeren et al.	1966	05004922	nonguideline[5]
67	Klumpar	1970	05013003	nonguideline[5]
68	Knauf and Schulze	1973	05021060	aerated treatments[9]
69	Knauf et al.	1973	--	nonguideline[4]
70	Koeman et al.	1977	05003152	nonapplicable[6]
71	Korn and Earnest	1974	05000819	nonguideline[5]
72	Lavaur and Arnolt	1977	05007515	no data on endosulfan[8]
73	Leski	1975	05014842	secondary data[3]
74	Loeb and Kelly	1963	--	nonguideline[5]
75	Ludemann and Neumann	1962	05007514	nonguideline[5]
76	Ludemann and Neumann	1961	05015466	insufficient data[11]
77	Luessen and Schlimme	1971	05007474	nonapplicable[6]
78	Lutz-Ostertag and Kantelip	1970	05005984	insufficient data[11]
79	Macek et al.	1969	05003107	insufficient data[11]
80	Macek	1975	05014041	mixture of pesticides[12]
81	Madsen	1969	05010322	nonapplicable[6]
82	Maier-Bode	1969	05003106	secondary data[3]
83	Malhotra and Katiyar	--	05008934	nonapplicable[6]
84	Martens	1971	05015623	nonapplicable[6]
85	Mawdesley-Thomas	1971	05004845	secondary data[3]
86	Maghaddam	1975	05018665	nonapplicable[6]
87	Moulton	1973	05004408	nonguideline[5]
88	Muirhead-Thompson	1973	--	plastic test container[9]
89	Mulla	1962	05020175	exotic species[1]
90	Mulla	1963	05011390	nonapplicable[6]
91	Navjarajan et al.	1979	05020465	nonapplicable[6]
92	Nishiushi	1978	05010084	nonapplicable[6]
93	Nishiushi	1977	05011073	nonapplicable[6]
94	Novocol	1963	00006207	nonapplicable[6]

Appendix Table E-18. Additional studies that were submitted to support the reregistration of Endosulfan but did not pass initial screen. Data discrepancies responsible for rejection are listed.

Number	Reference	Year	Access Number	Discrepancy
95	Olney	1972	05007651	nonguideline[4]
96	Palmer-Jones and Forester	1958	05003399	secondary data[3]
97	Palmer-Jones	1959	--	no raw data[3]
98	Paul et al.	1976	05004415	no controls
99	Peng	1973	05004541	secondary data[3]
100	Pickering and Henderson	1966	05014941	aerated exposure[9]
101	Plapp et al.	1978	05004012	nonguideline[5]
102	Poels and Strik	1975	05010957	insufficient data[11]
103	Ramakrishnam	1979	05015001	insufficient data[11]
104	Ramma	1969	00003882	insufficient data[11]
105	Reddy and Gomathy	1977	05003351	exotic species[1]
106	Reinert and Parke	1975	--	insufficient data[11]
107	Reith et al.	1969	05005963	nonapplicable[6]
108	Roberts	1975	05020593	nonguideline[5]
109	Roberts et al.	1984	256129	control mortality too high[13]
110	Roberts	1972	05004409	nonguideline[5]
111	Roberts	1972	05003062	nonguideline[5]
112	Roberts	1975	05003476	nonguideline[5]
113	Rosales et al.	1979	05013839	nonguideline[4]
114	Rosen	1967	--	exotic species[1]
115	Sander and Cope	1968	0510360	unreadable[2]
116	Sanders	1969	05009242	no raw data[3]
117	Sanders	1972	05017538	nonguideline[5]
118	Santharam et al.	1976	05005072	endosulfan purity not given[13]
119	Saradamma and Nair	1968	05005446	no controls[13]
120	Sarup et al.	1965	05004360	formulation not given[13]
121	Sarup et al.	1971	05010059	exotic species[1]
122	Schoettger	1970	--	secondary data[3]
123	Schoettger and Mauck	--	05018314	secondary data[3]
124	Shaw and Fischang	1962	05004263	insufficient data[11]
125	Sidhu and Dhawan	1977	05004372	insufficient data[11]

Appendix Table E-18. Additional studies that were submitted to support the reregistration of Endosulfan but did not pass initial screen. Data discrepancies responsible for rejection are listed.

Number	Reference	Year	Access Number	Discrepancy
126	Singh and Malhotra	1975	05004376	insufficient data[11]
127	Smith et al.	1963	--	nonguideline[5]
128	Stevenson and Walker	1974	--	secondary data[3]
129	Stute	1961	05015588	insufficient data[11]
130	Stroud and Martin	1967	--	nonguideline[5]
131	Takkem et al.	1978	--	exotic species[1]
132	Tan	1973	--	insufficient data[11]
133	Timmaiah	1976	05006293	nonapplicable[6]
134	Todd and Reed	1969	05007472	mixture of pesticides[12]
135	Torr et al.	1973	05008474	plastic test container[9]
136	Tuttle and Arvizo	1965	00012512	insufficient data[11]
137	U.S. EPA	1976	BA007902	old chemical analysis[13]
138	U.S. EPA	1976	BA007904	mixture of pesticides[12]
139	U.S. EPA	1976	--	old chemical analysis[13]
140	U.S. EPA	1978	05014443	nonguideline[4]
141	Van Rensburg and VanHamburg	1975	05015149	exotic species[1]
142	Van Dyk and Greeff	1977	05008664	nonguideline[4]
143	Velisicol	1977	00003772	secondary data[3]
144	Vieth	1978	05020223	nonapplicable[6]
145	Walsh	1975	05003229	secondary data[3]
146	Walsh	--	--	nonapplicable[6]
147	Walsh	1973	05003365	nonapplicable[6]
148	Walters	1976	05006295	insufficient data[11]
149	Ware and Roan	1970	05004032	secondary data[3]
150	Westigard	1973	05011397	insufficient data[11]
151	White	1970	05011241	insufficient data[11]
152	Wiackowski and Herman	1968	05004032	insufficient data[11]
153	Williamson	1976	05005502	nonapplicable[6]
154	Wojtowski and Hess	1966	05012099	nonapplicable[6]
155	Yap	1975	05003147	no raw data[3]
156	U.S. Dept. of Interior	1964	00004335	nonguideline[5]

Appendix Table E-18. Additional studies that were submitted to support the reregistration of Endosulfan but did not pass initial screen. Data discrepancies responsible for rejection are listed.

Number	Reference	Year	Access Number	Discrepancy
157	Yunnus and Soon	1971	05004536	no raw data[3]
158	Zoecon	1976	00010855	secondary data[3]

[1]nonguideline species used.

[2]unreadable (too faint, blurred) copy of study results.

[3]study was a summary of data from several sources. Little to no information was provided on methodology used to collect data; no raw data provided for statistical validation.

[4]study contained information on environmental fate and did not contain data on ecological effects; study was conducted prior to current guidelines.

[5]study followed methodologies that were inconsistent with present-day guidelines.

[6]study provided no useful information applicable to registration guidelines.

[7]formulation/purity of endosulfan not provided.

[8]study did not contain data on endosulfan.

[9]procedural discrepancies(eg. temperature fluctuations, lack of controls) confounded effects in data.

[10]methods development paper; provides no useful information relative to guidelines.

[11]insufficient data to statistically validate conclusions.

[12]mixture of chemicals was tested; not possible to isolate effect due to endosulfan.

[13]data gaps confounded interpretation of data

REFERENCES

Abreu, O. C., P. Abramides, N. A. Bonilha, N. D. Neto. 1975. Toxic residues to the silkworm (*Bombyx mori* L.) On mulberry leaves after treatment with acaricides. Boletim de Industria Animal 32(2): 379-388. (Access Number 05014638) (INVALID: exotic species)

Alabaster, J. S. 1969. Survival of fish in 164 herbicides, insecticides, fungicides, wetting agents and miscellaneous substances. International Pest Control 11(2): 29-35. (Access Number 05002896) (INVALID: formulation unknown; test species unclear)

Ali, A. D., N. M. Bakry, M. A. Abdellatif, S. K. El-Sawaf. 1973. The control of greater wax moth, Galleria mellonella, by chemicals: susceptibility of the wax moth larvae and honey-bee workers to certain chemicals. Zeitshcrift fuer Angewandte Entomologie 74(2): 170-177 (Access Number 05019782) (Not reviewed due to unreadable copy)

Amminikutty, C. K., M. S. Sege 1978. Acute and chronic effect of Thiodan35 EC and Agallol '3' on kidney, stomach and intestine of the widow tetra, *Gymonccorynbus ternetzi* Eculerger. Indian Journal of Experimental Biology 16(2): 202-205. (Supplemental)

Amminikutty, C. K., and M. S. Rege. 1977. Effects of acute and chronic exposure to pesticides, Thiodan EC 35 and Agallol '3' on the liver of widow tetra *Gymnocorymbus ternetzi* (Boulenger). Indian Journal of Experimental Biology 15 (3): 197-200. (Access Number 05003131) (Supplemental: exotic fish; nonguideline)

Anderson, L. D., E. I. Atkins, Jr., F. F. Todd, S. B. McGregor 1962. Toxicity of pesticides to honeybees. Gleanings in Bee Culture 90(1): 152-153 (Access Number 05003871) (INVALID secondary Data)

Anonymous 1968. Washington State pesticide handbook 1968 (Access Number 00004409) (INVALID; secondary data)

Anonymous 1971. Analysis of the Endosulfan content of the Rhine, the Main and in bank filtrates. Gas- und Wasserfach, Wasser-Abwasser 112(9): 445-447. (Access Number 05010470) (Fate to review)

Arnold, A. J., P. H. Needham, and J. H. Stevenson. 1973. A self-powered portable insect suction sampler and its use to assess the effects of azinphos methyl and endosulfan on blossom beetle populations on oil seed rape. Ann. Appl. Biol. 75: 229-233 (NA–study focuses on new sampling technique).

Arora, H. C., S. K. Shrivastava, A. K. Seth 1971. Bioassay studies of some commercial organic insecticides. Part I. Studies with an exotic carp *Puntius sophore* (Ham.). Indian Journal of Environmenal Health 13(3): 226-233. (Access Number 05003743) (INVALID: unorthodox methodology)

Arzone, a. 1975. Investigations and proposals about pesticides declared harmless to useful insects. Apicoltore Moderno 66(1): 16-25. (Access Number 05007035) (INVALID: secondary data).

Atkins, E. L., Jr., and L. D. Anderson 1967. Toxicity of pesticides and other agricultural chemicals to honey bees: laboratory studies. (Unpublished study received 1/30/69 uner 9G0802; prepared by Univ. Calif. Riverside, Dept. Of Entomology) (Access Number 00001999) (Scientifically sound; supplemental) (Listed as ACCEPTABLE)

Atkins, E. L., E. A. Greywood-Hale, R. L. Macdonald, and D. T. Ferguson 1974. Effect of pesticide on apiculture. Project No. 1499 final report. University of California, Riverside (Access Number 00001999).

Atkins, E. L. Jr., and L. D. Anderson 1967. Toxcity of pesticides and other agricultural chemicals to honey bees (*Apis mellifera*): laboratory studies (scientifically sound)

Attri, B. S., P.L. Sharma 1969 Toxicity of some new insecticides to Indian honey bee (*Apis indica*) Pesticides 3(6): 27-29 (Access Number 05004597) (guidelines not established at time of study-- supplemental).(Listed as ACCEPTABLE)

Bartless, R. R. 1963. The contact toxicity of some pesticide residues to Hymenopterous parasites and coccinellid preditors. Journal of Economic Entomology 56(5): 694-698 (scientifically sound; nonguideline study)

Bartlett, B. R. 1963. The contact toxicity of some pesticide residues to hymenopterous parasites and Coccinellid predators. J. Econ. Entomol. 56(5): 694-698. (Access Number 05003978) (Scientifically sound; nonguideline study) (Listed as ACCEPTABLE)

Bartlett, B. R. 1966. Toxicity and acceptance of some pesticides fed to parasitic Hymenoptera and predatory Coccinellids. Journal of Economic Entomology 59(5): 1142-1149. (Access Number 05005640) (Scientifically sound; nonguideline study). (Listed as ACCEPTABLE)

Bartlett, B. R. 1964. The toxicity of some pesticide residues to adult Amblyseius hibisci, with a compilation of the effects of pesticides upon Phytoseiid mites. Journal of Economic Entomology 57(4): 559-562. (Scientifically sound; nonguideline study).

Bartlett, B. R. 1968. Outbreaks of two-spotted spider-mites and cotton aphids following pesticide treatment. I. Pest stimulation vs natural enemy destruction as the cause of outbreaks. Journal of Economic Entomology 61(1): 297-303 (Access Number 05009955). (Not reviewed; unreadable copy)

Bartlett, B. R. 1964. The toxicity of some pesticide residues to adult *Amblyseius hibisci*, with compilation of the effects of pesticides upon phytoseiid mites. Journal of Economic Entomology 57(4): 559-563 (Access Number 05004148) (scientifically sound; nonguideline study) (Listed as ACCEPTABLE)

Bartlett, R. R. 1966. Toxicity and acceptance of some pesticides fed to parasitic Hymenoptera and predatory coccinellids. Journal of Economic Entomology 59(5): 1142-1149. (Access Number 05005640) (Scientifically sound; nonguideline study).

Basak, P. K., S. K. Korar. 1977. A new method for the determination of safe concentrations of insecticides to protect fishes. Indian Journal of Environmental Health 19(4): 283-292 (Access Number 05004792) (Supplemental; wrong test species; only 168 hr toxicity reported instead of 96 hour; unorthodox methodology)

Basak, P.K. and K. K. Korar. 1976. Toxicity of six insecticides to fish. Geobios 3(6): 209-210 .

Beaver, J. B., P. Frnk, and M. Jaber. 1987. Endosulfan technical substance: a one generation reproduction study with the mallard (*Anas platyrhynchos*). Wildlife International Ltd., Easton, MD. (Access Number 40261302) (CORE)

Beavers, J. B. , P. Frank, and M. J. Jaber 1987. Endosulfan technical substance: a one generation reproduction study with the bobwhite quail (*Colinus virginianus*). Wildlife International Ltd., Easton, MD. (Access Number 402613-03) (CORE)

Beran, R. 1962. The question of Thiodan risks for bees. Anzeiger fuer Schaedlingskunde 35(3): 38-40. (Access Number 05011240) (INVALID: secondary data; irrelevant).

Binder, D. 1969. Source of fish poisoning in Rhine identified as insecticide. New York Times, June 26 (Access Number 05002082) (INVALID: newspaper article).

Boeri, R. H. And T. J. Ward. 1983. Acute toxicity of Endosulfan to embryos of the eastern oyster (*Crassostrea virginica*) and the fiddler crab (*Uca pugnax*). Energy Resources Co., Inc. Cambridge, MA (Access Number 128688) (CORE)

Bournoville, R., J. N. Tasei 1977. Comparative effects of some insecticides against harmful mirids of alfalfa, their predators and the pollinating apoids. Phytiatrie-Phytopharmacie 26(3): 185-192. (Access Number 05006362) (INVALID: secondary data).

Brettell, J. H. and M. W. Burgess 1973. A preliminary assessment of the effect of some insecticides on predators of cotton pests. Rhodesia Agricultural Journal 70: 103-104 (Access Number 05014828) (Insufficient data: no formulation given; no application rate)

Brueggemann., J. , L. Busch, U. Drescher-Kaden 1976 Chlorinated hydrocarbon residues in wild animals Pages 281-300 in L.A. Page editor, The 3rd International Wildlife Disease Conference: 1975, Munich, Germany. Plenum, New York. (Access Number 05014607) (Irrelevant)

Buccafusco, R. J. And B. H. Sleight. 1976. Acute toxicity of Endosulfan technical to bluegill (*Lepomis macrochirus*) EG&G Binomics, Wareham MA (Access Number BA007912; 38306) (CORE)

Butler, P. A., C. D. Kennedy, and R. L Schutzmann. 1978. Pesticide residues in estuarine mollusks, 1977 versus 1972. National Pesticide Monitoring Program. Pesticides Monitoring Journal 12(3): 99-101. (Access Number 05007483) (Supplemental; nonguideline study)

Celli, G. 1974. Conditions for the survival of the honeybee in the present agricultural systems. Annali, Accademia Nazionale di Agricoltura, Bologna 94(4): 395-411. (Access Number 05009720) (INVALID: Secondary data)

Chalfant, R. B. 1978. Chemical control of insect pests of greens in Georgia. Georgia Agricultural Experiment Station's Research Bulletin No. 216, Tifton, GA. (NA) (Access Number 05013293) (Irrelevant to registration standard).

Claeys, R. R., R. S. Caldwell, N. H. Cutshall, and R. Holton. 1975. Residues in fish, wildlife, and estuaries. Pesticides Monitoring Journal 9(1): 2-10 (Nonguideline study).

Clinch, P.G. 1967. The residual contact toxicity to honey bees of insecticides sprayed on to white clover (*Trifolium repens* L) in the laboratory. New Zealand Journal of Agricultural Research 10(2): 289-300. (Access Number 05008936) (Scientifically sound) (Listed as ACCEPTABLE)

Clinch, P.G. 1969. Laboratory determination of the residual fumigant toxicity to honey bees of insecticide sprays on white clover (*Trifolium repens* L). New Zealand Journal of Agricultural Research 12(1): 162-170 (Access Number 05002083) (Scientifically sound) (Listed as ACCEPTABLE)

Cockbill, G. F. 1979. The effect of ultra-low-volume aerial applications of Endosulfan applied against Glossina (Dipera: Glossinidae) on populations of non-target organisms in savannah woodland in Zimbabwe-Rhodesia. Bulletin of Entomological Research 69(4): 645-655.   (Access Number 05018055) (Irrelevant; nonguideline; exotic species)

Colburn, R. and D. Asquith. 1971. Tolerance of the sates of *Stethorus punctum* to selected insecticides and miticides. J. Econ. Entomol. 64(5): 1072-1074 (Access Number 05004007) (Listed as ACCEPTABLE; scientifically sound; rated as supplemental)

Conti, G. G., 1976. Pesticide residues in birds. Proceedings of the Italian Society of Natural Science and of the Civic Museum of Natural History of Milan 117(3/4): 149-158. (Access Number 05009415) (NA; no specific data on endosulfan)

Coutin, R. and J. Coulon 1966. Comparative toxicities of several insecticides against *Dasyneura brassicae* WINN and its principal parasite *Prosactogaster oebalus* WALK. Phytiatrie-Phytopharmacie 15(2): 105-111. (Access Number 05005993) (Listed as ACCEPTABLE: Scientifically sound; classified as supplemental)

Croft, B.A., and A. W. A. Brown. 1975. Responses of arthropod natural enemies to insecticides. Ann. Rev. Entomol. 20: 285 - 335 (INVALID: secondary data).

Croft, B. A., E. E. Nelson 1972 Toxicity of apple orchard pesticides to Michigan populations of *Amblyseius fallacis*. Environmental Entomology 1(5): 576-579. (Access Number 05009345) (Listed as ACCEPTABLE; Scientifically sound)

Dalela, R. C., M. C. Bhatnagar, and S. R. Verma. 1978. Histochemical studies on the effect of rogor and Thiodan on the activity of acid phosphatase in liver, muscles and kidney of *Channa gachua*. Indian Journal of Experimental Biology 16(10): 1099-1102. (Access Number 05003496) (Supplemental; exotic fish; no standard protocol)

Dalela, R. C., S. R. Verma, M.C. Bhatnagar 1978. Biocides in relation to water pollution. Part I: bioassay on the effects of a few biocides on freshwater fish , Channa gachuat. Acta Hydrochimica et Hydrobiologica 6(1): 15-25 (Access Number 05011396) (not reviewed)

Dalela, R. C., M. C. Bhatnagar, A. K. Tyagi, S. R. Verma 1978. Adenosine triphosphatase activity in few tissues of a fresh water teleost, *Channa gachua*, following *in vivo* exposure to Endosulfan. Toxicology 11(4): 361-368. (Access Number 05003504) (Supplemental; exotic fish; nonguideline protocol)

Davies, R. A. H., I. W. McIaren 1977. Tolerance of *Aphytis melinus* DEBACH to 20 orchard chemical treatments in relation to integrated control of red scale, *Aonidiella aurantii* (MASKELL). Australian Journal of Experimental Agricultural and Animal Husbandry 17(85): 323-328. (Access Number 05004003) (Listed as ACCEPTABLE; Scientifically sound)

Davis, P.W., Wedemeyer, G. A. 1971 Inhibition by organochlorine pesticides on Na+, K+-activated adensoinetriphosphatase activity in the brain of rainbow trout. Page 47 in Proceedings of the Western Pharmacology Society, Vol 14. Western Pharmacology Society. (Access Number 05003020) (INVALID: no raw data; insufficient data).

Davis, P. W., G. A. Wedemeyer 1971. Na$^+$, K$^+$-activated ATPase inhibition in rainbow trout: a site for organochlorine pesticide toxicity. Comparative Biochemistry and Physiology, Part B. 40(3): 823-827. (Access Number 05003996) (Supplemental; nonguideline study)

Dunachie, J. F., W. W. Fletcher 1969. An investigation of toxicity of insecticides to birds' eggs using the egg-injection technique. Annals of Applied Biology 64: 409-423. (Access Number 05005055) (Supplemental; nonguideline)

Dustan, G. G. 1965. Effect of Endosulfan (Thiodan) on Geese.   Pesticide Progress 3(6): 16 (INVALID; nonguideline; no raw data; not relevant).

Dyck, V. A. And G. C. Orlido. 1977. Control of the brown planthopper (*Nilaparvata lugens*) by natural enemies and timely application of narrow-spectrum insecticides. Pages 58-72, in Seminar on Rice Brown Planthopper Oct. 5 - 9, 19 76, Tokyo, Japan. (Access Number 0500740) (INVALID; nonguideline study; exotic species)

Earnest, R. 1970. Annual progress report: 1970 effects of pesticides on aquatic animals in the estuarine and marine environments. U.S. Fish and Wildlife Service, Fish Pesticide Research Laboratory. (Access Number 00001328) (Supplemental; temperature fluctuations)

Edwards, B. A. B. and P. J. Hodgson 1973. The toxicity of commonly used orchard chemicals to *Stethorus nigripes* (Coleoptera: Coccinellidae). Journal of the Australian Entomological Society 12(3): 222-224. (Access Number 05009430) (INVALID; exotic species; nonguideline study)

Eichner, M. 1973. Residue analysis of chlorinated insecticides and polychlorinated biphenyls in fish of Lake Constance, the upper Rhine and its tributaries and in these waters. Zeitschrift fuer Lebensmittel-Untersuchung und -Forschung 151(6): 376-383 (Access Number 05011225) (INVALID: application rate not given).

Elsey, K. D. and J. S. Cheatham 1976. Contact toxicity of insecticides to three natural enemies of the tobacco hornworm and tobacco budworm. Tobacco Science XX: 87-88. (Access Number 05010420) (Not reviewed; unreadable copy).

Elzorgani, G. A., A. M. Abdulla, M. E. T. Ali 1979. Residues of organochlorine insecticides in fishes of Lake Nubia. Bulletin of Environmental Contamination and Toxicology 22(1/2): 44-48. (Access Number 05004981) (INVALID: exotic species; application rates unknown; nothing on endosulfan).

Engel, D. 1959. Plant protectants harmless to bees. Suedwestdeutscher Imker 11: 140-141 (Access Number 05013910) (INVALID: secondary data).

Findlay, J. B. R. 1970. The effect on the scorpion, *Chelectonus jonesi* Pocock (Scopionidae), of insecticidal baits broadcast in the field for the control of Harvester Termite *(Hodotermes mossambicus)* Hagen. Phytophylactica 2: 213. (Access Number 05003994) (INVALID: exotic species; no raw data; no methodology reported)

Fishcher, R. 1983. The effect of HOE002671 OI ZD96 0002 (Endosulfan, active ingredient 95.9%) on rainbow trout (*Oncorhynchus mykiss*) in a static test. Pharm/Landwirtschaft, Frankfurt, FRD. (Access Number 136999) (CORE)

Glofke, E. 1976. Detection of bee-poisoning with 22 different insecticides. Land- und Forstwirtschaftliche Forschung 7: 125-129. (Access Number 05010079) (NA: nonguideline study; reports on a protocol).

Goerke, H., G. Eder, K. Weber, W. Ernst 1979. Patterns of organochlorine residues in animals of different trophic levels form the Weser estuary. Marine Pollution Bulletin 10(5): 127-132. (Access Number 05008230) (Irrelevant)

Gorbach, S. 1972. Terminal residues of Endosulfan. Proceedings 2nd Int. Conf. Pest. Chem. 6: 283-285 (Access Number 05012881) (INVALID: secondary data).

Gorecki, K. 1973 Harmful effects of insecticides used in Poland on the honey bee, *Apis mellifica*. Polskie Pismo Entomologiczne 43(1): 201 - 210 (Access Number 05012881) (Supplemental: nonguideline). (Listed as ACCEPTABLE)

Greichus, Y. A.,A. Greichus, H. A. Draayer, B. Marshall 1978. Insecticides, polychlorinated biphenyls and metals in African lake ecosystems. II. Lake McIlwaine, Rhodesia. Bulletin of Environmental Contamination and Toxicology 19(4): 444-453 (Access Number 05003116) (Irrelevant).

Grimm, L. , P. Hoppe 1972. Pesticide residues (chlorinated hydrocarbons) in the liver of capcaillie, *Tetrao urogallus*, and blackgame , *Lyrurus tetrix*. Tieraerxtliche Umschau 27(8): 391-395. (Access Number 05006068) (Irrelevant)

Gupta, P. K. and R. C. Gupta. 1979. Pharmacology, toxicology and degradation of endosulfan. A review. Toxicology 13: 115 - 130.

Gupta, P. K. And S. V. Chandra. 1975. The toxicity of Endosulfan in rabbits. Bulletin of Environmental Contamination and Toxicology 14(5): 513-519 (nonguideline study).

Gupta, P. K. 1976. Endosulfan-induced neurotoxicity in rats and mice. Bull. Environ. Contam. Toxicol. 15(6): 708-713 (Nonguideline study).

Hameed, S. F., R. L. Adlakha, and S. P. Giamzo. 1973. Relative toxicity of some insecticides to the workers of *Apis mellifera* L. Madras agric J. 60(7): 552-556. (Access Number 05004909) (INVALID: insufficient data).

Hamilton, J. T. and F. I. Attia. 1976. The susceptibility of the parasite *Apanteles glomeratus* L. (Hymenoptera: Braconidae) to insecticides. Journal of the Entomological Society of Australia 9: 24-25. (Access Number 05008939) (INVALID: Insufficient data).

Hansen, D. J. and L. R. Goodman 1980. Chronic toxicity tests with estuarine fishes. U.S. EPA, Gulf Breeze, FL (supplemental; no raw data)

Haragsimova, L. 1962. Effect of common plant-protection chemicals on the honeybee (*Apis mellifica* L.) in Czechoslovakia. Tagungsbericht, Deutsche Akademie der Landwirtschaftswissenshaften zu Berlin 54: 35-38. (Access Number 05010080) (Insufficient data; methodological details missing).

Harris, C. R., H. J. Svec 1969. Laboratory studies on the contact toxicity of some insecticides to honeybees. Pages 165-167, in Proceedings of the Entomological Society of Ontario, Volume 100, Entomological Society of Ontario, Guelph, Ontario, Canada. (Access Number 05010080) (Scientifically sound; supplemental). (Listed as ACCEPTABLE)

Henderson, C., Q. H. Pickering, and C. M. Tarzwell. 1959. Relative toxicity of ten chlorinated hydrocarbon insecticides to four species of fish. Trans. of the American Fisheries Society 8(1): 23-32.

(INVALID: endosulfan not reported).

Hoyt, S.C. 1969. Integrated chemical control of insects and biological control of mites on apple in Washington. J. Econ. Entomol. 62(1): 74-86 (INVALID: mixture of pesticides applied).

Hudson, R. H., R. K. Tucker, and C. A. Haegele. 19 72. Effect of age on sensitivity: acute oral toxicity of 14 pesticides to mallard ducks of several ages. Toxicology and Applied Pharmacology 22(4): 556-561. (Access Number 05003462) (Supplemental; upgradeable to Core if dose response data were provided).

Hunt, E. G. 1970 the effects of pesticides on pelicans, owls, pheasants, falcons, egrets, herons, aren't fully known. But could we do without birds? California's Health 27(8): 7-9 (Access Number 05004358) (not relevant).

Iren, Z.   1968. A study on chemical control of *Epicometis hirta poda* in relation to the toxicity in honeybees. Bitki Koruma Bulteni 8(2): 125-139. (Access Number 05015995) (Insufficient data to complete evaluation).

Johansen, C. 1960. Bee poisoning versus clover aphid control in red clover grown for seed. Journal of Economic Entomology 53(6): 1012-1015 (Supplemental; nonguideline study).

Johansen, C. A. 1972. Toxicity of field-weathered insecticide residues to four kinds of bees. Environmental Entomology 1 (3): 393-394 (Access Number 05000837) (Scientifically sound; nonguideline study). (Listed as ACCEPTABLE)

Jones, W. E. 1975. Detection of pollutants by fish tests. Water Treatment and Examiniation 24(2): 132-139 (Access Number 05004539) (Not relevant).

Joshi, F. L., J. C. Sharma 1973. Toxicity of certain insecticides to *Menochilus sexmaculatus* F. and *Xanthogramma* (*Ischiodon*) *scutellare* F. predating on mustard aphid, *Lipaphis erysimi* KAIT. JNKVV Research Journal 7(2): 112-112 (Access Number 05010085) (Listed as ACCEPTABLE; Scientifically sound)

Kader, H. A., B. Thayumanavan, and S. Krishnaswamy 1976. The relative toxicities of ten biocides on *Spicodiptomus chelospinus* RAJENDRAN (Copepoda). Comparative Physiology and Ecology 1(3): 78-82 (Access Number 05015005) (Scientifically sound; supplemental; nonguideline study).

Kader, N. H., B. Thayumanavan, S. Krishnaswamy 1976. The relative toxicities of ten biocides on *Spicodiaptomus chelospinus* RAJENDRAN (1973). Comparative Physiology and Ecology 1(3): 78-82. (Access Number 05003954) (Supplemental; nonguideline).

Kapil, R. P., D. P. S. Iamba, H. S. Brar 1972. Integration of bee behavior with aphid control for seed production of *Brassica campestris* var *toria*. Indian Journal of Entomology 33(2): 221-223 (Access Number 05003722) (not relevant to registration standard; exotic species).

Kapil, R. P. and D. P. S. Lamba   1974. Toxicity of some important insecticides to *Apis cerana* Fab.

Indian Journal of Entomology 36(1): 6-10. (Access Number 05003721) (NA; exotic species).

Kinter, D. L. And A. D. Forbis 1983. Acute toxicity of Thionex 3EC to bluegill sunfish (*Lepomis macrochirus*) Makhteshim Agan, Inc, New York. (Supplemental).

Kinter, D. And A. Forbis 1983. Acute toxicity of Thionex 50 WP to rainbow trout (*Oncorhynchus mykiss*). ABC Labos, Columbia, MO. (Access Number 00128655) (CORE for formulation 50WP)

Kinter, D. L. And A. D. Forbis 1983. Acute toxicity of Thionex 3EC to rainbow trout (*Oncorhynchus mykiss*). Makhteshim Agan, Inc., New York. (Access Number 00128656) (CORE for formulation 3EC).

Kinter, D, and A. Forbis. 1983. Acute toxicity of Thionex 50 WP to bluegill sunfish *(Lepomis macrochirus)*. ABC Laboratories, Columbia, MO. (Access Number 00128656) (CORE for formulation 50WP).

Kirknel, E. 1975. The effect of various insecticides in laboratory experiments with two aphid predators, the seven spotted ladybird (Coccinella septenpunctata L.) and larvae of hoverflies (*Metasyrphus corollae* Fabr.). Tidsskrift for Planteavl. 79(3): 393-404. (Access Number 05013237) (Listed as ACCEPTABLE; Scientifically sound)

Klapow, L. A., R. H. Lewis 1979. Analysis of toxicity data for California marine water quality standards. Journal of the Water Pollution Control Federation 51(8): 2054-2070. (Access Number 05019675) (INVALID: no original data on endosulfan).

Klingeren, B., J. H. Koeman, J. I Haaften 1966. A study on the are (Lepus europeus) in relation to the use of pesticides in a polder in the Netherlands. Pages 125-131, in N. W. Moore, editior, Pesticides in the Environment and their Effects on Wildlife. Proceedings of a NATO Advanced Study Institute, Oxford, England. (Access Number 05004922) (Supplemental; nonguideline study).

Klostermeyer, P.C. 1968. Progress report: corn earworm control. (Unpublished study received 6/9/69 under 279-2299l; prepared by Washington State Univ., Dept. Of Entology, Irrigated Agriculture Research and Extension Center) (Access Number 00003883) (scientifically sound; supplemental) (Listed as ACCEPTABLE)

Klumpar, J. 1970. Complex winter rape protection. Agrochemia 10(12): 356-360. (Access Number 05013003) (nonguideline study)

Knauf, W. And E. F. Schulze 1973. New findings on the toxicity of Endosulfan and its metabolites to aquatic organisms. Meded, Fac. Landbauwetensch 38(3): 717-732 (Access Number 05021060) (INVALID: aerated test solutions).

Knauf, W., Oeser and Boerner 1973. The effect of sublethal concentrations of Endosulfan to *Carassius auratus*. ???? : 255-261 (Depuration study–fate).

Knauf, W., and E. F. Schulze 1973. New findings on the toxicity of endosulfan and its metabolites to aquatic organisms. Mededelingen van de Faculteit Landbouwwetenschappen, Rijksuniversiteit, Gent

38(3): 717-732. (INVALID: aerated test solutions).

Koeman, J. H. 1977. Chemical control of the tsetse fly: harmful effects on the environment. Natuur en Techniek 45(7): 476-493 (Access Number 05005985) (INVALID: nonguideline)

Koeman, J. H., W. M. J. Den Boer, A. F. Feith, H. H. DeIongh, P.C. Spliethoff. 1978. Three years' observations on side effects of helicopter applications of insecticides used to exterminate *Glossina* species in Nigeria. Environmental Pollution 15(1): 31-59 (NA) (Access Number 05003152) (irrelevant to registration standard).

Korn, S., and R. Earnest. 1974. Acute toxicity of twenty insecticides to striped bass *Morone saxatilis*. California Fish and Game 60(3): 128-131 (Access Number 05000819) (Supplemental; doesn't meet guideline requirements).

Kundu, G.G. and J. K. Sharma 1974. Toxicity of some modern insecticides to the predator *Coccinella septempunctata* L. (Coleoptera). Annals of Arid Zone 13(4): 361-363 (Access Number 05004542) (Scientifically sound; Listed as ACCEPTABLE).

Lavaur, E., A. Arnold. 1977. Pesticides and wildlife: results of toxicological analyses performed on game from 1974 to 1976. Phytiatrie-Phytopharmacie 26(3): 159-167 (Access Number 05007515) (INVALID: no raw data; endosulfan only mentioned as being present).

Leski, R. 1975. Pesticides and bees. Progress in Agricultural Science 22(1): 83-95. (Access Number 05014842) (INVALID: secondary data).

Loeb, H. A., W. H. Kelly. 1963. Acute oral toxicity of 1,496 chemicals force-fed to carp. U.S. Fish and Wildlife Service Special Scientific Report (Fisheries) No. 471 (supplemental; nonguideline study).

Ludeman, J. A. 1972. Fish toxicity laboratory report, rainbow trout (Oncoryhnchus mykiss) Test No. 496 (Access Number 33020) (CORE for 4% Dust formulation)

Ludemann, D. and H. Neumann 1962. The effect of modern contact insecticides on fresh water animals Anzeiger fuer Schaedlingskunde 35: 5-9 (Access Number 05007514) (INVALID)

Luedemann, D. and H. Neumann 1961. Studies on the use of *Artemia salina* L. As test animal for the proof of contact insecticides. Zeitschrift fuer Analystische Zoologie 48: 325-332 (Access Number 05015466) (not fully reviewed--lacks mortality data).

Luessem, H. E. Schlimme 1971. Localization of the herbicide endosulfan in the Rhine and its effect on fish. Gas-und Wasserfach, Wasser-Abwasser 112(1): 18-21. (Access Number 05007474) (NA).

Lutz-Ostertag, Y., J.P. Kantelip 1970. The action of endosulfan on the genital tract of chicken and quail embryos *in vivo* and *in vitro*. Bulletin de la Societe Zoologique de France 95(3): 620. (Access Number 05005984) (only the abstract was reviewed).

Macek, K. J., M. A. Lindberg, S. Sauter, K, S. Buxton, and P. A. Costa 1976. Toxicity of four pesiticides

to water fleas and fathead minnows. U.S.EPA, Deluth, MN (Access Number 05008271) (CORE).

Macek, K. J. 1975. Acute toxicity of pesticide mixtures to bluegills. Bulletin of Environmental Contamination and Toxicology 14(6): 648-652 (Access Number 05014041) (INVALID; mixture of pesticides tested).

Macek, K. J., C. Hutchinson, and O. E. Cope 1969. The effects of temperature on the susceptibility of bluegills and rainbow trout to selected pesticides. Bulletin of Environmental Contamination 4(3): 174-183. (Access Number 05003107) (Supplemental and upgradeable to core if dose response data were provided).

Madsen, H.F. 1969. Integrated control of the fruit-tree leaf roller and the white apple leafhopper in British Columbia. Journal of Economic Entomology 62(6): 1351-1353. (Access Number 05010322) (not relevant to registration standard).

Maier-Bode, H. 1968. Properties, effect, residues and analytics of the insecticide Endosulfan. Pages 1-44 in F. A. Gunther, editor. Residue Reviews. Residues of Pesticides and Other Foreign Chemicals in Foods and Feeds. Vol 22. Springer, New York. (Access Number 05003106) (INVALID: Secondary data).

Malhotra, C. P., R. N. Katiyar 1975. Control of *Eublemma amabilis* MOORE--a serious predator of the lac insect, *Kerria lacca* (KERR): 1; Screening of insecticides for their safety to lac insect. Indian Journal of Entomology 37(4): 385- 396. (Access Number 05008934) (Irrelevant to registration standard).

Martens, P. 1971. Water pollution hazards due to the use of agricultural pesticides. Annales de Gembloux 77(1): 39-47. (Access Number 05015623) (Irrelevant to registration standards).

Mawdesley-Thomas, L.E. 1971. Toxic chemicals--the risk to fish. New Scientist 49(734): 74-75. (Access Number 05004845) (INVALID: Secondary data).

Mayer, F. L., and M. R. Ellersieck. 1986. Manual of acute toxicity: interpretation and data base for 410 chemicals and 66 species of freshwater animals. U.S. Department of the Interior, Fish and Wildlife Service, Resource Publication 160.

Moghaddam, H. J. 1975. The effects of Thiodan on the oviposition of seven-spotted ladybird beetles in their second generation. Entomologie et Phytopathologie Appliquees (38): 74-82. (Access Number 05018665) (Irrelevant to registration standards).

Moulton, T.P. 1973. The effects of various insecticides (especially Thiodan and BHC) on fish in the paddy-fields of West Malaysia. Malaysian Agricultural Journal 49(2): 224-253 (Access Number 05004408) (Supplemental)

Muirhead-Thompson, R. C. 1973. Laboratory evaluation of pesticide impact on stream invertebrates. Freshwater Biology 3: 479-498 (INVALID: plastic test chambers; plastic reservoirs; test chambers aerated; tap water used).

Mulla, M. S. 1963. Toxicity of organochlorine insecticides to the mosquito fish *Gambusia affinis* and the bullfrog *Rana catesbeiana*. Mosquito News 23(4): 299-303. (Access Number 05011390) (INVALID: wrong species; unclear whether active ingredient is being reported).

Mulla, M. S. 1962. Frog and toad control with insecticides. Pest Control 10 (Access Number 05020175) (Supplemental; no methods described).

Navjarajan Paul, A. V., R. Dass, R. Ahmed, B. Parshad. 1979. Effect of some insecticides on parasitism by the parasitoid *Trichogramma brasiliensis* (ASHMEAD). Zeitschrift Fuer Angewandte Entomologie 88(4): 399-403 (Access Number 05020465) (Irrelevant to the registration standard).

Needham, P. H., J. H. Stevenson. 1973. The toxicity of foraging honeybees, *Apis mellifera*, of endosulfan, malathion and azinphos-methyl applied to flowering oil seed rape, *Brassica napus*. Annals of Applied Biology 75 (2): 235-240. (Access Number 05004447) (scientifically sound) (Listed as ACCEPTABLE)

Nishiuchi, Y. 1978. The toxicity of manufactured agricultural chemicals to some freshwater organisms. Suisan Zoshoku 25(4): 145-147. (Access Number 05010084) (Irrelevant to registration standard).

Nishiushi, Y. 1977. Effect of chemicals on aquatic animals--proper evaluation of toxicity to fish. Kagaku To Beibutsu 15(7): 428-429 (Access Number 05011073) (Irrelevant to registration standard).

Novocol Chemical Manufacturing Company, Inc. 1963. Toxicity tests of selected chemicals at Patuxent, 1963 (Access Number 00006207) (NA).

Okada, I., H. Hoshiba 9170. A laboratory experiment on the toxicity of some insecticides on honeybee (*Apis mellifera*). Bulletin of the Faculty of Agriculture, Tamagawa University [Japan] 10: 79-85. (Access Number 05013090) (Scientifically sound) (Listed as ACCEPTABLE).

Olney, E. E. 1972. Transfer of pesticides through water, sediments and aquatic life, Washington., D. C. U.S. Dept. of Interior, Office of Water Resources Research (Access Number 05007651) (Fate study).

Palmer-Jones, T. and I. W. Forster. 1958. Agricultural chemicals and the beekeeping industry. New Zealand Journal of Agriculture 97: 298-299 (Access Number 05003399) (INVALID: secondary data).

Palmer-Jones, T. 1959. Effect on honey bee of Thiodan applied to broad beans in a cage. New Zealand Journal of Agricultural Reserach 2: 229-233 (scientifically sound; no raw data provided).

Palmer-Jones, T., I. W. Forester 1963. Effect on honey bees of Dipterex, Thiodan, and Phosdrin applied as sprays to white clover (*Trifolium repens*). New Zealand Journal of Agricultural Research 6(3/4): 303-306 (Access Number 05004412) (Scientifically sound; supplemental) (Listed as ACCEPTABLE).

Palmer-Jones, T. , I. W. Forster, G. I. Jeffery 1959. Effect on honey bees of DDT and Thiodan applied from the air as sprays to chou mollier. New Zealand Journal of Agricultural Research 2(3): 481-487 (Access Number 05004414/05004794) (field study scientifically sound). Both access numbers: (Listed as ACCEPTABLE).

Palmer-Jones, T. 1958. Laboratory methods for measuring the toxicity of pesticides to honey bees. New Zealand Journal of Agricultural Research 1: 290-300. (Access Number 05004413) (Scientifically sound; no statistics run) (Listed as ACCEPTABLE).

Paul, A. V. N., M. Mcharansundaram and T. R. Subramarjan 1976. Effect of insecticides on the survival and emergence of egg parasites, *Trichogramma spp*. Madras Agricultural Journal, 63(8/10): 557-560. (Access Number 05004415) (INVALID: no controls).

Peng, T. S. 1973. The significance of sump-ponds in harvesting paddy-field fishes in North Krian, Perak. Malayan Nature Journal 26(1/2): 26-31. (Access Number 05004541) (INVALID: secondary data).

Pickering, Q.H., and C. Henderson 1966. The acute toxicity of some pesticides to fish. Ohio Journal of Science 66(5): 508-513. (Access Number 05014941) (INVALID: aerated test vessels).

Plapp, F. W., Jr., and D. L. Bull 1978. Toxicity and selectivity of some insecticides to *Chrysopa carvea*, a predator of the tobacco budworm. Envir. Entomol. 7(3): 431-434. (Access Number 05004012) (Scientifically sound; supplemental; nonguideline study).

Poels, C.L.M., J. J. T. W. A. Strik. 1975. Chronic toxic effects of the water of the fiver Rhine upon rainbow trout. Pages 81-91, in Sublethal Effects of Toxic Chemical on Aquatic Animals, Proceedings of the Swedish-Netherlands Symposium, Elsevier. (Access Number 05010957) (Not evaluated; only makes mention of endosulfan).

Ramakrishnan, C. N. Rajamohan, T.R. Subramaniam. 1974. Effect of inseciticidal sprays on the pollinators of sunflower. Madras Agricultural Journal 61(6): 175-177 (Access Number 05015001) (NA; insufficient data).

Rammer, I. A. 1969. Project number and title: 015 Thiodan: RC-174 (Access Number 00003882) (insufficient data).

Reddy, t. G., and S. Gomathy. 1977. Toxicity and respiratory effects of pesticides Thiodan on catfish, *Mystus vittatus*. Indian Journal of Environmental Health 19(4): 360-363. (Access Number 05003351) (INVALID: exotic species; no raw data).

Reinert, H. K., G.S.E. Parke 1975 Report: static 96-hr toxicity study of Mobil Chemical Co. sample Modown 4 lbs/g. Flowable-M in bluegill sunfish and rainbow trout (insfficient data to complete evaluation).

Reith, J. R., R. H. Drost, D. A. Schrijver, R.J. A. M. Albers 1969. Demonstration of toxic substances by trials with the fish species *Lebistes reticulatus*. Pharmaceutisch Weekblad 104(14): 273-287. (Access Number 05005963) (Irrelevant to registration standard).

Roberts, D. 1975. Sub-lethal effects of chlorinated hydrocarbons on bivalves. Marine Pollution Bulletin 6(2): 20 - 24. (Access Number 05020593) (Supplemental; nonguideline study).

Roberts, N. L., and C. N. Phillips. 1983. The acute oral toxicity (LD_{50}) of Endosulfan technical to the

bobwhite quail (*Colinus virginianus*). Huntingdon Research Center, England. (Access Number 137189) (CORE)

Roberts, D. 1975. The effect of pesticides on byssus formation in the common mussel, *Mytilus edulis*. Environmental Pollution 8(4): 241-254 (Access Number 05003062) (supplemental; nonguideline).

Roberts, D. 1972. The assimilation and chronic effects of sub-lethal concentrations of Endosulfan on condition and spawning in common mussel *Mytilus edulis*. Marine Biology 16: 119-125. (Access Number 05004409) (Supplemental; nonguideline)

Roberts, N., C. Phillips, A. Anderson, I. Dawe, D. Charter and S. Cook. 1985. The effects of dietary inclusion of Endosulfan-technical on reproduction in the mallard duck. Huntingdon Research Centre, England (Access Number 146843) (Listed as ACCEPTABLE; Supplemental; no NOEL).

Roberts, N.L., R. H. Almond, I. S. Dawe, D. O. Chanter, and S. S. Cook. 1984. The effects of dietary inclusion of Endosulfan-technical on reproduction in the bobwhite quail. Huntingdon Research Centeer, England. (Access Number 256129/148992) (Invalid: control mortality too high).

Roberts, N.L., and C. N. Phillips. 1983. The acute oral toxicity (LD_{50}) of Endosulfan technical to the mallard duck (*Anas platyrhynchus*). Huntingdon Research Center, England. (Access Number 136998) (CORE)

Roberts. D. 1975. Differential uptake of Endosulfan by the tissues of *Mytilus edulis*. Bulletin of Environmental Contamination and Toxicology 13(2): 170-176 (Access Number 05003476) (Supplemental; nonguideline).

Rosales, M.T.L., A. V. Botello, H. Bravo, E. F. Mandelli 1979. PCBs and organochlorine inseciticides in oysters from coastal lagoons of the Gulf of Mexico, Mexico. Bulletin of Environmental Contamination and Toxicology 21(4/5): 652-656. (Access Number 05013839)
(may fulfill core requirement for marine effects–residues only)

Rosen, D. 1967. Effect of commercial pesticides on the fecundity and survival of *Aphytis holoxanthus* (Hymenoptera: Aphelinidae). Israel J. Agric. Res. 17(1): 47-52 (nontest species).

Sander, M. O., and O. B. Cope 1968. The relative toxicities of several pesticides to naiads of three speices of stoneflies. Limnol. and Oceanog. 13(1): 112-117. (Access Number 0510360) (Invalid: unreadable copy).

Sanders, H. O. 1972. Toxicity of some insecticides to four species of Malacostracan crustaceans. U.S. Fish and Wildlife Service Technical Paper, Washington, D. C. (Access Number 05017538) (Supplemental; nonguideline; only adults tested).

Sanders, H. O. 1969. Toxicity of pesticides to the crustacean, *Gammarus lacustris*. U.S. Fish and Wildlife Service Technical Paper 25. Washington D.C. (Access Number 05009242) (supplemental; not reviewable since no raw data; only adults tested).

Santharam, K.R., B. Thayumanavan, and S. Krishnaswamy. 1976. Toxicity of some insecticides to *Daphnia carinata* King, an important link in the food chain in the freshwater ecosystems. Indian Journal of Ecology 3(1): 70-73. (Access Number 05005072) (INVALID: purity not given; test temperatures fluctuate too widely).

Saradamma, K., M. R. G. K. Nair 1968. Relative toxicity of insecticides to adults of *Microbracco brevicornis* (Wesmael) (Braconidae). Agricultural Research Journal of Kerala 6(2): 98-100. (Access Number 05005446) (INVALID: no controls).

Sarup, P., D. S. Singh, M. L. Srivastava, R. N. Singh. 1971. Laboratory evaluation of pesticides against the adults of an important parasite. *Bracon brevicornis* Wesmael (Braconidae: Hymenoptera) of some crop pests. Indian Journal of Entomology 33(3): 346-349. (Access Number 05010059 (INVALID: exotic species).

Sarup, P. , M. G. Jotwani, D. S. Singh 1965 Further studies on the effect of some important insecticides on *Coccinella septempurctata* L. (Coleoptera: coccinellidae). Indian Journal of Entomology 27(1): 72-76. (Access Number 05004360) (INVALID: neither formulation or method of application presented).

Schimmel, S. C., J. M. Patrick, Jr., and A. J. Wilson, Jr. 1976. Acute toxicity to and bioconcentration of endosulfan by estuarine animals. In press: Proc. ASTM Symposium on Aquatic Toxicology, Memphis, TN (Oct 1976). (Access Number 05005824 (CORE for 30% and 70% formulations)

Schoettger R. A. 1970. Toxicology of Thiodan in several fish and aquatic invertebrates. Pages 1 to 31 in U.S. Fish and Wildlife Service Investigations in Fish Control. Dept. of Interior, Washington, DC.

Schoettger, R. A., W. L. Mauck. 1978. Toxicity of experimental forest insecticides to fish and aquatic invertebrates. Pages 11-27 in Proceedings of the First and Second USA-USSR Symposia on the Effects of Pollutants Upon Aquatic Ecosystems (Access Number 05018314) (INVALID: Secondary data).

Searle, C. M. S. L. 1964. The reduction in toxicity of some insecticides to a parasitic insect by the addition of oil. South African Journal of Agricultural Science 7(2): 271-276 (Access Number 05006416) (Listed as ACCEPTABLE; Scientifically sound; supplemental).

Searle. C. M. S. L. 1965. The susceptibility of *Pauridia peregrina* TIMB to some pesticide formulations. Journal of the Entomological Society of South Africa 27(2): 239-249. (Access Number 05005572) (Listed as ACCEPTABLE; Scientifically sound; supplemental).

Shaw, R. R. and W. J. Fischang. 1962. The effects of certain newer pesticides on honey bees. American Bee Journal 102: 312-313. (Access Number 05004263) (Insufficient data to meet screen).

Sidhu, A. S. and A. K. Dhawan. 1977. Parasites of the cotton leafroller and the effect of insecticides on their survival. Pesticides 11(11): 28-29. (Access Number 05004372) (insufficient data to meet screen).

Singh, M., P I. Sharma, H. S. Dhaliwal. 1974. Toxicity of insecticides to honey bee workers, *Apis cerana indica*. Pesticides 8(12): 28-29. (Access Number 05003360) (scientifically sound) (Listed as ACCEPTABLE).

Singh, R. , R. K. Malhotra 1975. Fatal effect of insecticide-treated aphids on *Coccinella septempunctata*. Current Science 44: 325-326. (Access Number 05004376) (Insufficient data).

Smith, F. F., T. J. Henneberry, and A. L. Boswell 1963. The pesticide tolerance of *Typhlodromus fallacis* (Garman) and *Phytoseiulus persimilis* A.H. with some observations on the predator efficiency of *P. Persimilis*. J. Econ. Entomol. 56(3): 274-278 (Nonguideline study).

Stevenson, J. H. 1968. Laboratory studies on the acute contact and oral toxicities of insecticides to honeybees. Annals of Applied Biology 61(3): 467-472 (Access Number 05004151) (Listed as ACCEPTABLE).

Stevenson, J. H. 1978. The acute toxicity of unformulated pesticides to worker honey bees (*Apis mellifera* L). Plant Pathology 27(1): 38-40 (Access Number 05001991) (Scientifically sound) (Listed as ACCEPTABLE)

Stevenson, J. H., J. Walker 1974. Bee poisoning by insecticides in Britain 1966-1973. Bee World 55(2): 64-67 (Access Number 05004383) (INVALID: secondary data).

Stroud, R. H. and R. G. Martin 1967. Fish conservation highlights 1963-1967. Sport Fishing Institute, Washington, D.C. (Nonguideline).

Stute, K. 1961. Results of several years tests and observations on the insecticide Thiodan and its relation to bees. Anzeiger fuer Schaedlingskunde und Pflanzenschutz XXIV(11): 161-163. (Access Number 05015588) (Insufficient data to pass screen).

Takken, W. , F. Balk, R. C. Jansen, J. H. Koeman. 1978. The experimental application of insecticides from a helicopter for the control of riverine populations of Glossina tachinoides in West Africa. VI. Observations on Side-effects. Pans 24(4): 455-466 (Access Number 05020239) (INVALID: exotic species).

Tan, S.P. 1973. The significance of sump-ponds in harvesting paddy-field fishes in North Krian, Perak. Malayan Nature Journal 26(1/2) (Insufficient data to complete review)

Tasei, J. N., J. Capou, D. Michaud 1977. Effect of some pesticides on a solitary bee: *Megachile pacifica* Panz. Apidologie 8(2): 111-127.   (Access Number 05013358) (Scientifically sound) (Listed as ACCEPTABLE)

Teotia, T.P.S. and G. C. Tiwari 1972. Toxicity of some important insecticides to the Coccinellid predator, *Coccinella septempunctata* L.. Labdev, Part B 10(1): 17-18. (Access Number 05013372/05008943) (Listed as ACCEPTABLE; Scientifically sound; suppletmental; no raw data)

Thimmaiah, C. 1976. Effect of insecticides on the fibre properties and yeild of "Bhagya" cotton. Current Research 5(4): 65-66 (Access Number 05006293) (NA)

Todd, F. E. and C. B. Reed 1969. Pollen gathering of honey bees reduced by pesticide sprays. Journal of Economic Entomology 62(4): 865-867. (Access Number 05007472) (INVALID: mixture of

pesticides).

Toor, H. S. , K. Mehta, S. Chhina. 1973. Toxicity of insecticides (commercial formulations) to the exotic fish, common carp *Cyprinus carpio communis* L. Journal of Research, Punjab Agricultural University X(3): 342-345. (Access Number 05008474) (INVALID: plastic test containers; nonindigenous fish; only 2 treatments; 72 instead of 96 hr LC50).

Tuttle, D. M., G. L. Arvizo 1965. Control of alfalfa insect. University of Arizona Dept. of Entomology (Access Number 00012512) (INVALID–insufficient information to complete evaluation).

U.S. EPA 1976. Report on the toxicity of Metadan 2-2 to bluegill sunfish. U.S.EPA, Chemical and Biological Investigations Branch, Beltsville, MD (Access Number BA007904/33022) (Supplemental; tested mixture of active ingredients).

U.S. Dept. of Interior 1964. Pesticide wildlife studies–1963. Circular 199 (Access Number 00004335) (no protocol; nonguideline).

U.S. EPA 1976. Report on the toxicity of Thiodan to bluegill sunfish. U.S. EPA, Chemical and Biological Investigation Branch, Beltsville, MD (Supplemental)

U.S. EPA 1976. Report on the toxicity of Thiodan to rainbow trout. U.S. EPA Chemical and Biological Investigations Branch, Beltsville, MD (Access Number BA007902) (INVALID: chemical analysis over 2-yrs old).

U.S. EPA 1976. Report on the toxicity of Thiodan to rainbow trout. U.S. EPA, Chemical and Biological Investigation Branch, Beltsville, MD (Access Number BA007901)(CORE for 50WP formulation).

Van Rensburg, N. J., H. Van Hamburg. 1975. Grain sorghum pests: an integrated control approach. Pages 151-162, *in* H.J. R. Durr, J. H. Gilimoee, and S. Neser, editors, Proceedings of the 1st Congress of the Entomological Society of Southern Africa, Entomolgical Society of Southern Africa, Pretoria, South Africa. (Access Number 05015149) (exotic species; irrelevant to registration standard).

VanDyk, L.P. C.G. Greeff. 1977. Endosulfan pollution of rivers and streams in the Loskop Dam cotton-growing area. Agrochemophysica 9(3): 71-75 (Access Number 05008664) (Study under review by Fate 1980)

Velsicol Chemical Corporation 1977. Technical Endosulfan formulation guide (Access Number 00003772) (INVALID: secondary data).

Vieth, F. 1978. Use of pesticide analysis in the clarificationof fish deaths Fischerei und Flussbiologie 30: 209-214 (Access Number 05020223) (NA)

Walsh, A. H. and W.E. Ribelin. 1973. Lesions of pesticide poisoning in fish. Toxicology and Applied Pharmacology 25(3): 485 (Access Number 05003365) (NA)

Walsh, A. H., and W. E. Riblin (no date) Lesions of pesticide poisoning in fish. Toxicol. App. Pharmac

25(3) 483.

Walsh, A. H. 1975. The pathology of pesticide poisoning in fish. Dissertation Abstracts International B 35(7): 3423 (Access Number 05003229) (INVALID: secondary data)

Walters, P. J. 1976. Susceptibility of three *Stethorus spp*. (Coleoptera: Coccinellidae) to selected chemicals used in N.S.W. apple orchards. Aust. Ent. Soc. 15: 49-52. (Access Number 05006295) (Insufficient data for review: % active ingredient and formulation not reported).

Ware, G. W. and C.C. Roan. 1970. Interaction of pesticides with aquatic microorganisms and plankton. Pages 15-45 *In* F.A. Gunther, editor. Residue Reviews 33, New York. (Access Number 05004032) (INVALID: Secondary data)

Westigard, P. H. 1973. The biology of an deffect of pesticides on *Deraeocoris brevis piceatus* (Heteroptera: Miridae). Canadian Entomologist 105(8): 1105-1111. (Access Number 05011397) (Insufficient data to complete review).

White, B. R. 1970. Insecticides on rape: effect on honey bees of Endosulfan (Thiodan) applied from the air as a spray to rape. Australasian Beekeeper 72(5): 123-127. (Access Number 05011241) (Insufficient data to complete review).

Wiackowski, S. K., E. Herman 1968. Laboratory investigations on the effect of insecticides on adults of primary and secondary aphid parasites. Polskie Pismo Entomologiczne XXXVIII(3): 593-600. (Access Number 05004032) (Insufficient data to complete review: test concentrations not reported).

Williamson, J. M. 1976. Sanitary position and methods of control in Rhodesia in 1975. Bulletin de l'Officie International des Epizooties 86: 627-633 (Access Number 05005502) (NA).

Wojtowski, F., and E. Hess. 1966. Effect of Thiodan, Toxaphene, Terpentol, and Lindane-activated Terpentol on honey bees. Roczniki Wyzszej Szkoly Rolniczej W. Poznaniu XXIX: 291-299. (Access Number 05012099) (not relevant to registration standard).

Yap, H. H., D. Desaiah, L. K, Cutkomp, and R. B. Koch. 1975. *In vitro* inhibition of fish brain ATPase activity by cyclodiene insecticides and related compounds. Bulletin of Environmental Contamination and Toxicology 14(2): 163167. (Access Number 05003147) (Supplemental; no raw data; nonguideline).

Yunnus, A., L. G. Soon. 1971. A problem in the use of insecticides in paddy fields in west Malaysia-- a case study. Malaysian Agricultural Journal 48(2): 167-183. (Access Number 05004536) (no raw data; nonguideline; Supplemental)

Zoecon Corporation 1976. Acute and chronic *Daphnia magna* studies with technical Altosid. (Access Number 00010855) (INVALID: Secondary data)

APPENDIX F: ECOLOGICAL RISK ASSESSMENT

A means of integrating the results of exposure and ecotoxicity data is called the quotient method. For this method, risk quotients (RQs) are calculated by dividing exposure estimates by ecotoxicity values, both acute and chronic.

$$RQ = EXPOSURE/TOXICITY$$

RQs are then compared to OPP's levels of concern (LOCs). These LOCs are criteria used by OPP to indicate potential risk to nontarget organisms and the need to consider regulatory action. The criteria indicate that a pesticide used as directed has the potential to cause adverse effects on nontarget organisms. LOCs currently address the following risk presumption categories: (1) **acute high** - potential for acute risk is high, regulatory action may be warranted in addition to restricted use classification (2) **acute restricted use** - the potential for acute risk is high, but this may be mitigated through restricted use classification (3) **acute endangered species** - the potential for acute risk to endangered species is high, regulatory action may be warranted, and (4) **chronic risk** - the potential for chronic risk is high, regulatory action may be warranted. Currently, EFED does not perform assessments for chronic risk to plants, acute or chronic risks to nontarget insects, or chronic risk from granular/bait formulations to mammalian or avian species.

The ecotoxicity test values (*i.e.*, measurement endpoints) used in the acute and chronic risk quotients are derived from the results of required studies. Examples of ecotoxicity values derived from the results of short-term laboratory studies that assess acute effects are: (1) LC_{50} (fish and birds) (2) LD_{50} (birds and mammals) (3) EC_{50} (aquatic plants and aquatic invertebrates) and (4) EC_{25} (terrestrial plants). Examples of toxicity test effect levels derived from the results of long-term laboratory studies that assess chronic effects are: (1) LOEC (birds, fish, and aquatic invertebrates) (2) NOEC (birds, fish and aquatic invertebrates) and (3) MATC (fish and aquatic invertebrates). For birds, mammals, and all aquatic organisms, the NOEC is the ecotoxicity test value used in assessing chronic risk. Other values may be used when justified. Risk presumptions, along with the corresponding RQs and LOCs are summarized in **Tables F-1** through **F-3**.

Table F-1. Risk presumptions for terrestrial animals (birds and wild mammals)

Risk Presumption	RQ	LOC
Acute High Risk	EEC^1/LC_{50} or LD_{50}/ft^2 or LD_{50}/day^3	0.5
Acute Restricted Use	EEC/LC_{50} or LD_{50}/ft^2 or LD_{50}/day (or $LD_{50} < 50$ mg/kg)	0.2
Acute Endangered Species	EEC/LC_{50} or LD_{50}/ft^2 or LD_{50}/day	0.1
Chronic Risk	EEC/NOEC	1

[1] abbreviation for Estimated Environmental Concentration (ppm) on avian/mammalian food items

[2] $\dfrac{mg/ft^2}{LD_{50} * wt.\ of\ bird}$ [3] $\dfrac{mg\ of\ toxicant\ consumed/day}{LD_{50} * wt.\ of\ bird}$

Table F-2. Risk presumptions for aquatic animals

Risk Presumption	RQ	LOC
Acute High Risk	EEC^1/LC_{50} or EC_{50}	0.5
Acute Restricted Use	EEC/LC_{50} or EC_{50}	0.1
Acute Endangered Species	EEC/LC_{50} or EC_{50}	0.05
Chronic Risk	$EEC/NOEC$	1

[1] EEC = (ppm or ppb) in water

Table F-3. Risk presumptions for plants

Risk Presumption	RQ	LOC
Terrestrial and Semi-Aquatic Plants		
Acute High Risk	EEC^1/EC_{25}	1
Acute Endangered Species	EEC/EC_{05} or NOEC	1
Aquatic Plants		
Acute High Risk	EEC^2/EC_{50}	1
Acute Endangered Species	EEC/EC_{05} or NOEC	1

[1] EEC = lbs ai/A
[2] EEC = (ppb/ppm) in water

Exposure and Risk to Nontarget Terrestrial Animals

For pesticides applied as a nongranular product (*e.g.*, liquid, dust), the estimated environmental concentrations (EECs) on food items following product application are compared to LC_{50} values to assess risk. The predicted 0-day maximum and 56-day mean residues of a pesticide that may be expected to occur on selected avian or mammalian food items immediately following a direct single application at 1 lb ai/A and 2 lbs ai/A are presented in **Table F-4**.

Table F-4. Estimated environmental concentrations on avian and mammalian food items (ppm) following single applications at 1 lb ai/A and 2lbs. a.i./A.

Application Rate	Food Items	EEC (ppm) Predicted Maximum Residue[1]	EEC (ppm) 56 Day Mean[1]
1 lb a.i./A	Short grass	240	27
	Tall grass	110	10
	Broadleaf/forage plants and small insects	135	11
	Fruits, pods, seeds, and large insects	15	1
2 lbs. a.i./A	Short grass	480	54
	Tall grass	220	21
	Broadleaf/forage plants and small insects	270	21
	Fruits, pods, seeds, and large insects	30	2

[1] Predicted maximum and mean residues are for a 1 lb ai/a application rate and are based on Hoerger and Kenaga (1972) as modified by Fletcher *et al.* (1994).

Predicted residues (EECs) resulting from multiple applications are calculated in various ways. Uncertainties in the terrestrial EECs are primarily associated with a lack of data on interception and subsequent dissipation from foliar surfaces. Willis and McDowell (1987) summarized seven studies which evaluated the foliar persistence of endosulfan on a variety of crops. Foliar half-lives ranged from 1 to 5 days on a variety of crops (cotton, grapes, pears, tobacco, alfalfa, beets, and leafy vegetables) in studies conducted in California, Arizona, Kentucky, Canada, and Australia. The mean of the 13 reported half-life values was 3.2 days (standard deviation of 1.4 days). The upper 90th percent confidence interval value for the mean (4 days) was used as the foliar dissipation rate for modeling purposes.

Birds

The acute risk quotients for broadcast applications of nongranular products are tabulated below. At the maximum application rate of 2 lbs. a.i./A, acute high risk, restricted use, and endangered species LOCs were exceeded for birds feeding on short grasses; acute restricted use and endangered species LOCs were exceeded for birds feeding on tall grasses and broadleaf plants/insects. At the lowest application rate of 1 lb. a.i./A, the acute endangered species LOC was exceeded for birds feeding on tall grasses and broadleaf plants/insects.

Chronic risks were evaluated using both the maximum and 56-day mean estimated environmental concentrations (**Table F-5**). Chronic LOCs were exceeded for birds feeding on all food items except seeds based on estimated peak residues following treatment with 2 lbs. a.i./A. Chronic LOCs were exceed for birds feeding on short grass when RQs were based on the 56-day average residues following treatment with 2 lbs. a.i./A.

Table F-5. Avian acute and chronic risk quotients for single application of nongranular products (broadcast) based on a (bobwhite quail) LC_{50} of 805 ppm and a (mallard duck) NOEC of 30 ppm.

Site/App. Method	App. Rate (lbs ai/A)	Food Items	Max. EEC (ppm)	56-Day Avg. EEC (ppm)	LC_{50} (ppm)	NOEC	Acute RQ (EEC/ LC_{50})	Chronic RQ max EEC/NOEC	Chronic RQ 56-day EEC/NOEC
tobacco (aerial) tomatoes (aerial), cantelope (ground)	1 lb a.i./A	Short grass	240	27	805	30	0.30[b]	8[d]	0.9
		Tall grass	110	10	805	30	0.14[C]	14[d]	0.3
		Broadleaf plants / Insects	135	11	805	30	0.17[C]	4.5[d]	0.4
		Seeds	15	1	805	30	0.02	0.5	0.03
Potatoes (aerial)	2 lbs a.i./A	Short grass	480	54	805	30	0.60[a]	16[d]	1.8[d]
		Tall grass	220	21	805	30	0.27[b]	7[d]	0.7
		Broadleaf plants / Insects	270	21	805	30	0.34[b]	9[d]	0.7
		Seeds	30	2	805	30	0.04	1[d]	0.07

[a] exceeds acute high, acute restricted and acute endangered species LOCs.

b exceeds acute restricted and acute endangered species LOCs.
C exceeds acute endangered species LOCs
d exceeds chronic LOC

Based on a rate of 2 application of 1.5 lbs. a.i./A, acute high risk, restricted use and endangered species LOCs are exceeded for birds feeding on short grass (**Table F-6**); acute restricted use and endangered species LOCs are exceeded for birds feeding on tall grass and broadleaf plants/insects. At an application rate of 1 lb a.i./A applied 3 times, acute restricted use and endangered species LOCs are exceeded for birds feeding on short grass and broadleaf plants/insects. Acute endangered species LOCs are exceeded for birds feeding on tall grass. Chronic LOCs are exceeded for birds feeding on all food items except seeds.

Table F-6. Avian acute and chronic risk quotients for multiple applications of nongranular products (broadcast) based on a (bobwhite quail) LC$_{50}$ of 805 ppm and a (mallard duck) NOEC of 30 ppm .

Site/App. Method	App.Rate (lbs ai/A) No. of Apps.	Food Items	Peak EEC[1] (ppm)	56-Day EEC (ppm)	LC$_{50}$ (ppm)	NOEC (ppm)	Acute RQ (EEC/ LC$_{50}$)	Chronic RQ peak EEC/ NOEC)	56-day EEC/NO EC
tobacco (aerial) tomatoes (aerial), cantelope (ground)	1 (3)	Short grass	332	81	805	30	0.41[b]	11.00[d]	2.7 [d]
		Tall grass	152	35	805	30	0.19[C]	5.10[d]	1.2 [d]
		Broadleaf plants/Insects	187	41	805	30	0.23[b]	6.20[d]	1.4 [d]
		Seeds	21	4	805	30	0.03	0.70	0.10
apples (airblast), grapes (aerial), pecans (airblast)	1.5 (2)	Short grass	424	81	805	30	0.53[a]	14.00[d]	2.7[d]
		Tall grass	194	34	805	30	0.24[b]	6.50[d]	1.1 [d]
		Broadleaf plants/Insects	238	39	805	30	0.30[b]	7.90[d]	1.3 [d]
		Seeds	26	4	805	30	0.03	0.87	0.13

a   exceeds acute high, acute restricted and acute endangered species LOCs.
b   exceeds acute restricted and acute endangered species LOCs.
C exceeds acute endangered species LOCs
d exceeds chronic LOC

Mammals

Birds and mammals have similar responses to xenobiotics, their differences being more quantitative rather than qualitative. Birds have lower hepatic microsomal mono-oxygenase and A-esterase activity than do mammals. Therefore, birds are more susceptible than mammals to both organophosphate and carbamates in general. Since endosulfan does not present an acute risk to endangered birds, mammals are also presumed to be protected.

Estimating the potential for adverse effects to wild mammals is based upon EEB's draft 1995 SOP of mammalian risk assessments and methods used by Hoerger and Kenaga (1972) as modified by Fletcher *et al.* (1994). The concentration of endosulfan in the diet that is expected to be acutely lethal to 50% of the test population (LC$_{50}$) is determined by dividing the LD$_{50}$ value (usually rat LD$_{50}$) by the % (decimal of) body weight consumed. A risk quotient is then determined by dividing the EEC by the

derived LC_{50} value. Risk quotients are calculated for three separate weight classes of mammals (15, 35, and 1000 g), each presumed to consume four different kinds of food (grass, forage, insects, and seeds). The acute risk quotients for broadcast applications of nongranular products are tabulated below. At the lowest (1 lbs a.i./A) and highest (2 lbs a.i./A) application rates, acute high risk, restricted use and endangered species LOCs are exceeded for all sized herbivores and insectivores feeding on short grasses, tall grasses, and broadleaf plants/insects.

Table F-7. Mammalian (herbivore/insectivore) acute risk quotients for single application of nongranular products (broadcast) based on a rat LD_{50} of 10 mg/kg.

Site/ App. Method/ Rate in lbs ai/A	Body Wt. (g)	% Body Weight Consumed	Rat LD_{50} (mg/kg)	EEC (ppm) Short Grass	EEC (ppm) Tall Grass	EEC (ppm) Broadleaf plants / Insects	Acute RQ[1] Short Grass	Acute RQ Tall Grasses	Acute RQ Broadleaf plants / Insects
tobacco (aerial) tomatoes (aerial), cantelope (ground) 1 lb a.i./A	15	95	10	240	110	135	23[2]	10[2]	13 [2]
	35	66	10	240	110	135	16[2]	7.2[2]	8.9 [2]
	1000	15	10	240	110	135	3.6[2]	1.6[2]	2.0 [2]
Potatoes (aerial) 2 lbs. a.i./A	15	95	10	480	220	270	46[2]	21[2]	26 [2]
	35	66	10	480	220	270	32[2]	15[2]	18 [2]
	1000	15	10	480	220	270	7[2]	3.3[2]	4.0[2]

[1] RQ = $\dfrac{\text{EEC (ppm)}}{LD_{50}\text{ (mg/kg)/ \% Body Weight Consumed}}$

[2] acute high risk, restricted use and endangered species LOCx exceeded.
[3] acute restricted use and endangered species LOCs exceeded.
[4] acute endangered species LOC exceeded.

Acute risk quotients for a single application of nongranular products exceeded acute high risk, restricted use and endangered species LOCs for small (15 g) granivores while acute restricted use and endangered species LOCs are exceeded for intermediate-sized granivores at application rates as high as 2 lbs. a.i./A (**Table F-8**). Acute restricted use and endangered species LOCs were exceeded for both small and intermediate-sized granivores following a single application of 1 lb./A.

Table F-8. Mammalian (granivore) acute risk quotients for single application of nongranular products (broadcast) based on a rat LD_{50} of 10 mg/kg.

Site/ Application Method/ Rate in lbs ai/A	Body Weight (g)	% Body Weight Consumed	Rat LD_{50} (mg/kg)	EEC (ppm) Seeds	Acute RQ[1] Seeds
tobacco (aerial) tomatoes (aerial), cantelope (ground) 1 lb a.i./A	15	21	10	15	0.32[3]
	35	15	10	15	0.22[3]
	1000	3	10	15	0.05
Potatoes (aerial) 2 lbs. a.i./A	15	21	10	30	0.64[2]
	35	15	10	30	0.45[3]

Table F-8. Mammalian (granivore) acute risk quotients for single application of nongranular products (broadcast) based on a rat LD$_{50}$ of 10 mg/kg.

Site/ Application Method/ Rate in lbs ai/A	Body Weight (g)	% Body Weight Consumed	Rat LD$_{50}$ (mg/kg)	EEC (ppm) Seeds	Acute RQ[1] Seeds
	1000	3	10	30	0.03

[1] RQ = $\dfrac{\text{EEC (ppm)}}{\text{LD}_{50}\text{ (mg/kg)/ \% Body Weight Consumed}}$

[2] acute high risk, restricted use and endangered species LOCs exceeded.

[3] acute restricted use and endangered species LOCs exceeded.

[4] acute endangered species LOC exceeded.

Table F-9. Mammalian (herbivore/insectivore) acute risk quotients for multiple applications of nongranular products (broadcast) based on a rat LD$_{50}$ of 10 mg/kg.

Site/ Application Method/ Ratein lbs ai/A	Body Weight (g)	% Body Weight Consumed	Rat LD$_{50}$ (mg/kg)	EEC (ppm) Short Grass	EEC (ppm) Tall Grass	EEC (ppm) Broadleaf plants/Insects	Acute RQ[a] Short Grass	Acute RQ Tall Grasses	Acute RQ Broadleaf plants / Insects
tobacco (aerial)	15	95	10	332	152	187	32[b]	14[b]	18[b]
tomatoes (aerial), cantelope (ground)	35	66	10	332	152	187	22[b]	10	12[b]
1 lb a.i./A 3 applications	1000	15	10	332	152	187	5[b]	2.3[b]	2.8[b]
apples (airblast), grapes	15	95	10	424	194	238	40[b]	18[b]	23[b]
(aerial), pecans (airblast)	35	66	10	424	194	238	28[b]	13[b]	16[b]
1.5 lbs a.i/A 2 applications	1000	15	10	424	194	238	6.3[b]	2.9[b]	3.6[b]

[a] RQ = $\dfrac{\text{EEC (ppm)}}{\text{LD}_{50}\text{ (mg/kg)/ \% Body Weight Consumed}}$

[b] acute high risk, restricted use and endangered species LOCs exceeded.

Acute risk quotients for mammals exceeded acute high risk, restricted use and endangered species LOCs for small (15 g) granivores (**Table F-10**). Acute restricted use and endangered species LOCs were exceeded for small and intermediate-sized (35 g) granivores following multiple applications of endosulfan.

Table F-10. Mammalian (granivore) acute risk quotients for multiple applications of nongranular products (broadcast) based on a rat LD_{50} of 10 mg/kg.

Site/ Application Method/Rate in lbs ai/A	Body Weight (g)	% Body Weight Consumed	Rat LD_{50} (mg/kg)	EEC (ppm) Seeds	Acute RQ[1] Seeds
tobacco (aerial)	15	21	10	21	0.44 [3]
tomatoes (aerial), cantelope (ground)	35	15	10	21	0.31[3]
1 lb a.i./A					
3 applications	1000	3	10	21	0.06[4]
apples (airblast), grapes (aerial),	15	21	10	26	0.55[2]
pecans (airblast)	35	15	10	26	0.39[3]
1.5 lbs a.i/A					
2 applications	1000	3	10	26	0.08[4]

[1] RQ = $\dfrac{\text{EEC (ppm)}}{\text{LD}_{50}\text{ (mg/kg)/ \% Body Weight Consumed}}$

[2] acute high risk, restricted use and endangered species LOCx exceeded.

[3] acute restricted use and endangered species LOCs exceeded.

[4] acute endangered species LOC exceeded.

Chronic risk quotients for multiple applications, *i.e.*, 3 applications of 1 lb a.i./A and 2 applications of 1.5 lbs. a.i./A, exceeded chronic LOCs using both the predicted peak and mean 56-day residues (**Table F-11**).

Table F-11. Mammalian Chronic Risk Quotients for Multiple Applications of Nongranular Products (Broadcast) Based on a rat NOAEC of 15 ppm in a 2-generation reproduction study.

Site/ Application/ Method	Application Rate (lbs ai/A) (No. Apps.)	Food Items	Maximum EEC[1] (ppm)	56 Day Average EEC (PPM)	NOEC (ppm)	Chronic RQ Max. EEC/NOEC	Chronic RQ 56-day EEC/NOEC
tobacco (aerial) tomatoes (aerial), cantelope (ground)	1 lb a.i./A 3 applications	Short Grass	333	81	15	2.2[2]	4.4[2]
		Tall Grass	152	35	15	10[2]	2.3[2]
		Broadleaf plant/Insects	187	41	15	12[2]	2.7[2]
		Seeds	21	4	15	1.4[2]	0.3
apples (airblast), grapes (aerial), pecans (airblast)	1.5 lbs a.i/A 2 applications	Short Grass	424	81	15	28[2]	5.4[2]
		Tall Grass	194	34	15	13[2]	2.3[2]
		Broadleaf plant/insects	238	39	15	16[2]	2.6[2]
		Seeds	26	4	15	1.7[2]	0.3

[1] Based on Fletcher without degradation.

[2] Exceeds chronic LOC

Exposure and Risk to Nontarget Freshwater Aquatic Animals

Freshwater Fish

Acute high risk, restricted use and endangered species LOCs are exceeded for freshwater fish on all of the crops modeled (range: 1.2 - 23) (**Table F-13a**) using maximum application rates. Chronic LOCs are exceeded (range: 2.2 - 44) for freshwater fish on all the major crops modeled using maximum application rates. When maximum application rates are used in conjunction with a 300-ft buffer, high acute risk and chronic risk LOCs were exceeded (**Table F-13b**). Even using typical application rates and a 300-ft buffer (Table F-13c) acute risk quotients (range: 0.3- 16) exceed acute high risk LOCs and except for apples, chronic risk LOCs (RQ range: 0.5 - 29) are exceeded.

Table F13-a. Risk quotients for freshwater fish based on a rainbow trout 96-hr LC_{50} of 0.83 ppb and a rainbow trout NOAEC of 0.11 ppb.

Site/ Application Method	Rate in lbs as/A (No. of Apps.)	LC_{50}* (ppb)	NOEC (ppb)	EEC Initial/ Peak (ppb)	EEC 21-Day Average	Acute RQ (EEC/LC_{50})	Chronic RQ (EEC/NOEC)
apples	1.5 (2)	0.83	0.11	0.98	0.24	1.18[a]	2.2
Cotton	1.5 (2)	0.83	0.11	7.53	2.51	9.08[a]	23
Lettuce	1.5 (2)	0.83	0.11	5.01	1.27	6.04[a]	12[b]
Pecan	1.5 (2)	0.83	0.11	16.7	3.80	20.1[a]	35[b]
Potato	3.0 (1)	0.83	0.11	5.23	1.62	6.30[a]	15[b]
Tobacco	1.0 (3)	0.83	0.11	6.87	1.76	8.28[a]	16[b]
Tomato	1.0 (3)	0.83	0.11	19.1	4.87	23.0[a]	44[b]

[a] exceeds acute high risk, restricted use, and acute endangered species LOCs.
[b] exceeds chronic LOC.

Table F-13b. Risk quotients for freshwater fish based on a rainbow trout 96-hr LC_{50} of 0.83 ppb and a rainbow trout NOAEC of 0.11 ppb using maximum application rates and a 300-ft spray drift buffer.

Site/ Application Method	Rate in lbs as/A (No. of Apps.)	LC_{50}* (ppb)	NOEC (ppb)	EEC Initial/ Peak (ppb)	EEC 21-Day Average	Acute RQ (EEC/LC_{50})	Chronic RQ (EEC/NOEC)
apples	1.5 (1)	0.83	0.11	0.56	0.10	0.68[a]	0.9[b]
Cotton	0.4 (3)	0.83	0.11	7.89	2.57	9.5[a]	23[b]
Lettuce	0.7 (2)	0.83	0.11	2.99	0.51	3.6[a]	4.6[b]
Pecan	0.9 (2)	0.83	0.11	12.5	2.49	15[a]	23[b]
Potato	0.8 (1)	0.83	0.11	3.91	0.99	4.7[a]	9[b]
Tobacco	0.9 (1)	0.83	0.11	6.27	1.11	7.6[a]	10[b]
Tomato	0.7 (3)	0.83	0.11	18.6	4.54	22[a]	41[b]

[a] exceeds acute high risk, restricted use, and acute endangered species LOCs.
[b] exceeds chronic LOC.

Table F13-c. Risk quotients for freshwater fish based on a rainbow trout 96-hr LC$_{50}$ of 0.83 ppb and a rainbow trout NOAEC of 0.11 ppb using typical application rates and a 300-ft buffer.

Site/ Application Method	Rate in lbs as/A (No. of Apps.)	LC$_{50}$* (ppb)	NOEC (ppb)	EEC Initial Peak (ppb)	EEC 21-Day Average	Acute RQ (EEC/LC$_{50}$)	Chronic RQ (EEC/NOEC)
apples	1.5 (1)	0.83	0.11	0.26	0.05	0.3[b]	0.46 [c]
Cotton	0.4 (3)	0.83	0.11	3.01	0.82	3.6[a]	7.5 [c] b
Lettuce	0.7 (2)	0.83	0.11	1.39	0.24	1.7[a]	2.2 [c]
Pecan	0.9 (2)	0.83	0.11	10.3	2.32	12[a]	21 [c]
Potato	0.8 (1)	0.83	0.11	1.20	0.29	1.4[a]	2.6 [c]
Tobacco	0.9 (1)	0.83	0.11	1.86	0.31	2.2[a]	2.8 [c]
Tomato	0.7 (3)	0.83	0.11	13.0	3.16	16[a]	29 [c]

[a] exceeds acute high risk, restricted use, and acute endangered species LOCs.
[b] exceeds restricted use and acute endangered species LOCs.
[c] exceeds chronic LOC.

Freshwater Invertebrates

The acute and chronic risk quotients for freshwater invertebrates are tabulated below (**Table F-14a**). Acute high risk, restricted use and endangered species levels of concern are exceeded (RQ range: 0.86 - 3.3) for freshwater invertebrates on all of the crops modeled except for apples (RQ = 0.17) where acute restricted use and endangered species LOCs are exceeded. For all of the major crops, chronic LOCs were exceeded (range: 5.6 - 93). Using maximum application rates and a 300-ft buffer (**Table F-14b**), acute high risk, restricted use and endangered species were exceeded for all crops (RQ range 0.52 - 3.2) except apples (RQ = 0.1) while chronic LOCs were exceeded for all crops (RQ range: 2.3 - 87). Using typical application rates and a 300-ft buffer (**Table F-14c**), acute high risk, restricted use and endangered species LOCs were exceed on 4 crops (cotton, grapes, pecans and tomatoes) while chronic LOCs (RQ range: 1 - 61) were exeeded for all of the crops

Table F-14a. Risk quotients for freshwater invertebrates based on a scud 48-hr LC$_{50}$ of 5.8 ppb and a scud NOEC of 0.07 ppb using maximum application rates.

Site/ Application Method	Rate in lbs as/A (No. of Apps.)	LC$_{50}$* (ppb)	NOEC (ppb)	EEC Initial/ Peak (ppb)	EEC 21-Day Mean	Acute RQ (EEC/LC$_{50}$)	Chronic RQ (EEC/NOEC)
apples	1.5 (2)	5.8	0.07	0.98	0.39	0.17[b]	5.6[c]
Cotton	1.5 (2)	5.8	0.07	7.53	3.16	1.30[a]	45[c]
Lettuce	1.5 (2)	5.8	0.07	5.01	2.16	0.86[a]	31[c]
Pecan	1.5 (2)	5.8	0.07	16.7	5.35	2.88[a]	76[c]
Potato	3.0 (1)	5.8	0.07	5.23	2.43	0.90[a]	35[c]
Tobacco	1.0 (3)	5.8	0.07	6.87	2.61	1.18[a]	37[c]
Tomato	1.0 (3)	5.8	0.07	19.1	6.50	3.29[a]	93[c]

[a] exceeds acute high risk, restricted use, and acute endangered species LOCs.
[b] exceeds acute restricted use and acute endangered species LOCs.   [c] exceeds chronic LOC.

Table F-14b. Risk quotients for freshwater invertebrates based on a scud 48-hr LC_{50} of 5.8 ppb and a scud NOEC of 0.07 ppb using maximum application rates and a 300-ft buffer.

Site/ Application Method	Rate in lbs as/A (No. of Apps.)	LC_{50}* (ppb)	NOEC (ppb)	EEC Initial/ Peak (ppb)	EEC 21-Day Mean	Acute RQ (EEC/LC_{50})	Chronic RQ (EEC/NOEC)
apples	1.5 (1)	5.8	0.07	0.56	0.16	0.10[b]	2.3[c]
Cotton	0.4 (3)	5.8	0.07	7.89	3.18	1.36[a]	45[c]
Lettuce	0.7 (2)	5.8	0.07	2.99	0.91	0.52[b]	13[c]
Pecan	0.9 (2)	5.8	0.07	12.5	3.89	2.16[a]	56[c]
Potato	0.8 (1)	5.8	0.07	3.91	1.38	0.67[b]	20[c]
Tobacco	0.9 (1)	5.8	0.07	6.27	1.81	1.08[b]	26[c]
Tomato	0.7 (3)	5.8	0.07	18.6	6.11	3.21[a]	87[c]

[a] exceeds acute high risk, restricted use, and acute endangered species LOCs.
[b] exceeds acute restricted use and acute endangered species LOCs. [c] exceeds chronic LOC.

Table F-14c. Risk quotients for freshwater invertebrates based on a scud 48-hr LC_{50} of 5.8 ppb and a scud NOEC of 0.07 ppb using typical application rates and a 300-ft buffer.

Site/ Application Method	Rate in lbs as/A (No. of Apps.)	LC_{50}* (ppb)	NOEC (ppb)	EEC Initial/ Peak (ppb)	EEC 21-Day Mean	Acute RQ (EEC/LC_{50})	Chronic RQ (EEC/NOEC)
apples	1.5 (1)	5.8	0.07	0.26	0.08	0.05	1.1[c]
Cotton	0.4 (3)	5.8	0.07	3.01	1.12	0.52[a]	16[c]
Lettuce	0.7 (2)	5.8	0.07	1.39	0.42	0.24[b]	6.0[c]
Pecan	0.9 (2)	5.8	0.07	10.3	3.28	1.8[a]	47[c]
Potato	0.8 (1)	5.8	0.07	1.20	0.39	0.21[b]	5.6[c]
Tobacco	0.9 (1)	5.8	0.07	1.86	0.50	0.32[b]	7.1[c]
Tomato	0.7 (3)	5.8	0.07	13.0	4.25	2.2[a]	61[c]

[a] exceeds acute high risk, restricted use, and acute endangered species LOCs.
[b] exceeds acute restricted use and acute endangered species LOCs. [c] exceeds chronic LOC.

Estuarine and Marine Animals

Acute high risk, restricted use and endangered species LOCs were exceeded (RQ range: 10 - 191) for estuarine/marine fish on all of the major crop uses modeled (**Table F-15a**) using maximum application rates. Chronic LOCs were also exceeded (RQ range: 24 - 487) for estuarine/marine fish on all of the major crop uses. Maximum application rates in conjunction with a 300-ft buffer resulted in acute high risk, restricted use, and endangered species LOCs exceeded for all crops (RQ range: 5.6 - 186); chronic LOCs were also exceeded for all crops (RQ range: 10 - 454) (**Table F-15b**). Using typical application rates and a 300-ft buffer (**Table F-15c**) acute high risk, restricted use and endangered species LOCs (RQ range: 3 - 130) and chronic LOCs (RQ range: 5 - 316) are exceeded for all crops.

Table F-15a. Risk quotients for estuarine/marine fish based on a stripped bass 96-hr LC$_{50}$ of 0.1 ppb and an NOEC of 0.01 ppb* using maximum application rates.

Site/ Application Method	Rate in lbs as/A (No. of Apps.)	LC$_{50}$* (ppb)	NOEC (ppb)	EEC Initial/ Peak (ppb)	EEC 21-Day Average	Acute RQ (EEC/LC$_{50}$)	Chronic RQ (EEC/NOEC)
apples	1.5 (2)	0.1	0.01	0.98	0.24	9.8[a]	24[b]
Cotton	1.5 (2)	0.1	0.01	7.53	2.51	75[a]	251[b]
Lettuce	1.5 (2)	0.1	0.01	5.01	1.27	50[a]	127[b]
Pecan	1.5 (2)	0.1	0.01	16.7	3.80	167[a]	380[b]
Potato	3.0 (1)	0.1	0.01	5.23	1.62	52[a]	162[b]
Tobacco	1.0 (3)	0.1	0.01	6.87	1.76	69[a]	176[b]
Tomato	1.0 (3)	0.1	0.01	19.1	4.87	191[a]	487[b]

[a] exceeds acute high risk, restricted use, and acute endangered species LOCs.
[b] exceeds chronic LOC.

Table F-15b. Risk quotients for estuarine/marine fish based on a stripped bass 96-hr LC$_{50}$ of 0.1 ppb and an NOEC of 0.01 ppb* using typical application rates.

Site/ Application Method	Rate in lbs as/A (No. of Apps.)	LC$_{50}$* (ppb)	NOEC (ppb)	EEC Initial/ Peak (ppb)	EEC 21-Day Average	Acute RQ (EEC/LC$_{50}$)	Chronic RQ (EEC/NOEC)
apples	1.5 (1)	0.1	0.01	0.56	0.10	5.6[a]	10[b]
Cotton	0.4 (3)	0.1	0.01	7.89	2.57	79[a]	257[b]
Lettuce	0.7 (2)	0.1	0.01	2.99	0.51	299[a]	51[b]
Pecan	0.9 (2)	0.1	0.01	12.5	2.49	125[a]	249[b]
Potato	0.8 (1)	0.1	0.01	3.91	0.99	39[a]	99[b]
Tobacco	0.9 (1)	0.1	0.01	6.27	1.11	63[a]	111[b]
Tomato	0.7 (3)	0.1	0.01	18.6	4.54	186[a]	454[b]

[a] exceeds acute high risk, restricted use, and acute endangered species LOCs.
[b] exceeds chronic LOC.

Table F-15c. Risk quotients for estuarine/marine fish based on a stripped bass 96-hr LC$_{50}$ of 0.1 ppb and an NOEC of 0.01 ppb* using typical application rates and a 300-ft buffer.

Site/ Application Method	Rate in lbs as/A (No. of Apps.)	LC$_{50}$* (ppb)	NOEC (ppb)	EEC Initial/ Peak (ppb)	EEC 21-Day Average	Acute RQ (EEC/LC$_{50}$)	Chronic RQ (EEC/NOEC)
apples	1.5 (1)	0.1	0.01	0.26	0.05	2.6[a]	5[b]
Cotton	0.4 (3)	0.1	0.01	3.01	0.82	30[a]	82[b]
Lettuce	0.7 (2)	0.1	0.01	1.39	0.24	14[a]	24[b]
Pecan	0.9 (2)	0.1	0.01	10.3	2.32	103[a]	232[b]

Table F-15c. Risk quotients for estuarine/marine fish based on a stripped bass 96-hr LC$_{50}$ of 0.1 ppb and an NOEC of 0.01 ppb* using typical application rates and a 300-ft buffer.

Site/ Application Method	Rate in lbs as/A (No. of Apps.)	LC$_{50}$* (ppb)	NOEC (ppb)	EEC Initial/ Peak (ppb)	EEC 21-Day Average	Acute RQ (EEC/LC$_{50}$)	Chronic RQ (EEC/NOEC)
Potato	0.8 (1)	0.1	0.01	1.20	0.29	12[a]	29[b]
Tobacco	0.9 (1)	0.1	0.01	1.86	0.31	19[a]	31[b]
Tomato	0.7 (3)	0.1	0.01	13.0	3.16	130[a]	316[b]

Acute high risk, restricted use and endangered species LOCs are exceeded (RQ range 2.2 - 42) for estuarine/marine invertebrates on all crop uses modeled (**Table F-16a**) using maximum application rates. Chronic LOCs were also exceeded for estuarine/marine invertebrates (RQ range 7.8 - 130) at maximum application rates. Acute high risk, restricted use and endangered species LOCs are also exceeded (RQ range : 1.2 - 41) at for maximum application rates coupled with a 300-ft buffer (**Table F-16b**); chronic LOCs were exceeded for all crops (RQ range 3.2 - 122) at typical application rates. Using typical application rates and a 300-ft buffer (**Table F-16c**) acute high risk, restricted use and endangered species LOCs (RQ range: 0.6 - 29) are exceeded; chronic LOCs were exceeded for all crops (RQ range 2 - 85).

Table F-16a. Risk quotients for estuarine/marine invertebrate based on an Eastern oyster 48-hr LC$_{50}$ of 0.45 ppb and an Eastern oyster NOEC of 0.05 ppb using maximum application rates. The NOEC for Eastern oyster was based on the acute to chronic ratio (166:2) derived from freshwater invertebrate (daphnid) data.

Site/ Application Method	Rate in lbs as/A (No. of Apps.)	LC$_{50}$* (ppb)	NOEC (ppb)	EEC Initial/ Peak (ppb)	EEC 21-Day Average	Acute RQ (EEC/LC$_{50}$)	Chronic RQ (EEC/NOEC)
apples	1.5 (2)	0.45	0.05	0.98	0.39	2.2[a]	7.8[b]
Cotton	1.5 (2)	0.45	0.05	7.53	3.16	17[a]	63[b]
Lettuce	1.5 (2)	0.45	0.05	5.01	2.16	11[a]	43[b]
Pecan	1.5 (2)	0.45	0.05	16.7	5.35	37[a]	107[b]
Potato	3.0 (1)	0.45	0.05	5.23	2.43	12[a]	49[b]
Tobacco	1.0 (3)	0.45	0.05	6.87	2.61	15[a]	52[b]
Tomato	1.0 (3)	0.45	0.05	19.1	6.50	42[a]	130[b]

[a] exceeds acute high risk, restricted use, and acute endangered species LOCs.
[b] exceeds chronic LOC.

Table F-16b. Risk quotients for estuarine/marine invertebrate based on an Eastern oyster 48-hr LC$_{50}$ of 0.45 ppb and a brown shrimp NOAEC of 0.24 ppb using typical application rates.

Site/ Application Method	Rate in lbs as/A (No. of Apps.)	LC$_{50}$* (ppb)	NOEC (ppb)	EEC Initial/ Peak (ppb)	EEC 21-Day Average	Acute RQ (EEC/LC$_{50}$)	Chronic RQ (EEC/NOEC)
apples	1.5 (2)	0.45	0.05	0.56	0.16	1.2[a]	3.2[b]

Table F-16b. Risk quotients for estuarine/marine invertebrate based on an Eastern oyster 48-hr LC$_{50}$ of 0.45 ppb and a brown shrimp NOAEC of 0.24 ppb using typical application rates.

Site/ Application Method	Rate in lbs as/A (No. of Apps.)	LC$_{50}$* (ppb)	NOEC (ppb)	EEC Initial/ Peak (ppb)	EEC 21-Day Average	Acute RQ (EEC/LC$_{50}$)	Chronic RQ (EEC/NOEC)
Cotton	1.5 (2)	0.45	0.05	7.89	3.18	18[a]	64[b]
Lettuce	1.5 (2)	0.45	0.05	2.99	0.91	61[a]	18[b]
Pecan	1.5 (2)	0.45	0.05	12.5	3.89	28[a]	78[b]
Potato	3.0 (1)	0.45	0.05	3.91	1.38	8.7[a]	28[b]
Tobacco	1.0 (3)	0.45	0.05	6.27	1.81	14[a]	36[b]
Tomato	1.0 (3)	0.45	0.05	18.6	6.11	41[a]	122[b]

[a] exceeds acute high risk, restricted use, and acute endangered species LOCs.
[b] exceeds chronic LOC.

Table F-16c. Risk quotients for estuarine/marine invertebrate based on an Eastern oyster 48-hr LC$_{50}$ of 0.45 ppb and a mysid shrimp NOAEC of 0.24 ppb using typical application rates.

Site/ Application Method	Rate in lbs as/A (No. of Apps.)	LC$_{50}$* (ppb)	NOEC (ppb)	EEC Initial/ Peak (ppb)	EEC 21-Day Average	Acute RQ (EEC/LC$_{50}$)	Chronic RQ (EEC/NOEC)
apples	1.5 (1)	0.45	0.05	0.26	0.08	0.6 [a]	1.6
Cotton	0.4 (3)	0.45	0.05	3.01	1.12	6.7[a]	22[b]
Lettuce	0.7 (2)	0.45	0.05	1.39	0.42	3.1[a]	8.4[b]
Pecan	0.9 (2)	0.45	0.05	10.3	3.28	23[a]	66[b]
Potato	0.8 (1)	0.45	0.05	1.20	0.39	2.7[a]	7.8[b]
Tobacco	0.9 (1)	0.45	0.05	1.86	0.50	4.1[a]	10[b]
Tomato	0.7 (3)	0.45	0.05	13.0	4.25	29[a]	85[2]

[a] exceeds acute high risk, restricted use, and acute endangered species LOCs.
[b] exceeds chronic LOC.

APPENDIX G: SUMMARY OF INCIDENT DATA

Table G1. Summary of incident number by pesticide.

PESTNAME	Frequency	Percent	Cumulative Frequency	Cumulative Percent
2,4,5-TP (SILVEX)	1	0.0	1	0.0
2,4,5-TRICHLOROPHENOXYACETIC A	2	0.1	3	0.1
2,4-D	51	1.8	54	1.9
2,4-DB	1	0.0	55	1.9
4-AMINOPYRIDINE	13	0.4	68	2.3
ACEPHATE	6	0.2	74	2.5
ACETOCHLOR	2	0.1	76	2.6
ACID	9	0.3	85	2.9
ACIFLUORFEN	1	0.0	86	3.0
ACROLEIN	9	0.3	95	3.3
ALACHLOR	42	1.4	137	4.7
ALDICARB	9	0.3	146	5.0
ALPHA-ENDOSULFAN	3	0.1	149	5.1
ALUMINUM PHOSPHIDE	2	0.1	151	5.2
AMITRAZ	86	3.0	237	8.1
AMITROLE	1	0.0	238	8.2
ATRAZINE	47	1.6	285	9.8
AZINPHOS-METHYL	146	5.0	431	14.8
AZOXYSTROBIN	1	0.0	432	14.8
BASIC CUPRIC SULFATE	1	0.0	433	14.9
BENDIOCARB	12	0.4	445	15.3
BENEFIN	1	0.0	446	15.3
BENOMYL	57	2.0	503	17.3
BIFENTHRIN	2	0.1	505	17.3
BIPHENTHRIN	4	0.1	509	17.5
BLEACH	1	0.0	510	17.5
BRODIFACOUM	41	1.4	551	18.9
BROMACIL	6	0.2	557	19.1
BROMADIOLONE	4	0.1	561	19.3
BROMOXYNIL	2	0.1	563	19.3
BUTYLATE	2	0.1	565	19.4
CAPTAN	5	0.2	570	19.6
CARBARYL	15	0.5	585	20.1
CARBOFURAN	317	10.9	902	31.0
CARBOSULFAN	1	0.0	903	31.0
CHLORDANE	56	1.9	959	32.9
CHLORFENAPYR	2	0.1	961	33.0
CHLORIMURON-ETHYL	2	0.1	963	33.0
CHLOROTHALONIL	6	0.2	969	33.3
CHLORPYRIFOS	155	5.3	1124	38.6
CHLORSULFURON	2	0.1	1126	38.6
CLOMAZONE	85	2.9	1211	41.6
CLOPYRALID	12	0.4	1223	42.0
CLOPYRALID, MONOETHANOLAMINE S	3	0.1	1226	42.1
COPPER ETHYLENEDIAMINE COMPLEX	1	0.0	1227	42.1
COPPER SULFATE	6	0.2	1233	42.3
CRYOLITE	1	0.0	1234	42.3
CYANAZINE	17	0.6	1251	42.9
CYANIDE (COPPER)	1	0.0	1252	43.0
CYANIDE (POTASSIUM)	1	0.0	1253	43.0
CYCLOHEXIMIDE	1	0.0	1254	43.0
CYFLUTHRIN	4	0.1	1258	43.2
CYHALOTHRIN	4	0.1	1262	43.3
CYPERMETHRIN	9	0.3	1271	43.6
DALAPON	2	0.1	1273	43.7
DAZOMET	1	0.0	1274	43.7

PESTNAME	Frequency	Percent	Cumulative Frequency	Cumulative Percent
DCPA	1	0.0	1275	43.8
DDE	1	0.0	1276	43.8
DDT	43	1.5	1319	45.3
DIAZINON	175	6.0	1494	51.3
DICAMBA	5	0.2	1499	51.4
DICAMBA WITH DMA SALT OF 2,4-D	1	0.0	1500	51.5
DICAMBA, DIMETHYLAMINE SALT	10	0.3	1510	51.8
DICHLORVOS	3	0.1	1513	51.9
DICROTOPHOS	1	0.0	1514	52.0
DIELDRIN	43	1.5	1557	53.4
DIMETHENAMID	11	0.4	1568	53.8
DIMETHOATE	9	0.3	1577	54.1
DIMETHYL AMINE	8	0.3	1585	54.4
DIMETHYLAMINE	1	0.0	1586	54.4
DIPHACINONE	8	0.3	1594	54.7
DIQUAT DIBROMIDE	4	0.1	1598	54.8
DISULFOTON	8	0.3	1606	55.1
DITHIOPYR	30	1.0	1636	56.1
DIURON	25	0.9	1661	57.0
ENDOSULFAN	91	3.1	1752	60.1
ENDOTHALL	2	0.1	1754	60.2
ENDRIN	13	0.4	1767	60.6
EPTC	3	0.1	1770	60.7
ETHALFLURALIN	33	1.1	1803	61.9
ETHION	2	0.1	1805	61.9
ETHOPROP	8	0.3	1813	62.2
ETHYL PARATHION	44	1.5	1857	63.7
FAMPHUR	23	0.8	1880	64.5
FENAMIPHOS	13	0.4	1893	65.0
FENARIMOL	1	0.0	1894	65.0
FENOXAPROP-ETHYL	1	0.0	1895	65.0
FENPROPATHRIN	2	0.1	1897	65.1
FENSULFOTHION	8	0.3	1905	65.4
FENTHION	37	1.3	1942	66.6
FLUAZIFOP-BUTYL	2	0.1	1944	66.7
FLUMETSULAM	65	2.2	2009	68.9
FOMESAFEN	2	0.1	2011	69.0
FONOFOS	16	0.5	2027	69.6
FOSPIRATE	1	0.0	2028	69.6
GAMMA ISOMER OF BENZENE HEXACH	1	0.0	2029	69.6
GLYPHOSATE	187	6.4	2216	76.0
GLYPHOSATE, ISOPROPYLAMINE SAL	35	1.2	2251	77.2
GLYPHOSINE	1	0.0	2252	77.3
HEPTACHLOR	21	0.7	2273	78.0
HEXACHLOROEPOXYOCTAHYDRO-ENDO,	1	0.0	2274	78.0
HEXAZINONE	3	0.1	2277	78.1
IMAZAPYR	4	0.1	2281	78.3
IMAZAQUIN	4	0.1	2285	78.4
IMAZETHAPYR	5	0.2	2290	78.6
IMIDACLOPRID	1	0.0	2291	78.6
IPRODIONE	2	0.1	2293	78.7
ISAZOFOS	8	0.3	2301	79.0
ISOFENPHOS	1	0.0	2302	79.0
KARBUTILATE	1	0.0	2303	79.0
LINDANE (GAMMA-BHC 99% PURE)	5	0.2	2308	79.2
LINURON	4	0.1	2312	79.3
LIQUID NITROGEN FERTILIZER	1	0.0	2313	79.4
MALATHION	10	0.3	2323	79.7
MANCOZEB	3	0.1	2326	79.8
MANEB	3	0.1	2329	79.9
MECOPROP	1	0.0	2330	80.0
MEPIQUAT CHLORIDE	5	0.2	2335	80.1
METALAXYL	5	0.2	2340	80.3

```
METAM-SODIUM                        2      0.1       2342        80.4
METHAMIDOPHOS                       2      0.1       2344        80.4


                                                 Cumulative  Cumulative
PESTNAME                     Frequency  Percent   Frequency    Percent
_____
METHIDATHION                        6      0.2       2350        80.6
METHOMYL                            6      0.2       2356        80.9
METHOPRENE                          1      0.0       2357        80.9
METHYL NONYL KETONE                 1      0.0       2358        80.9
METHYL PARATHION                   35      1.2       2393        82.1

METOLACHLOR                        45      1.5       2438        83.7
METRIBUZIN                         23      0.8       2461        84.5
METSULFURON METHYL                  6      0.2       2467        84.7
MEVINPHOS                           3      0.1       2470        84.8
MIREX                               2      0.1       2472        84.8
MOLINATE                            2      0.1       2474        84.9
MONOCROTOPHOS                       2      0.1       2476        85.0
MSMA                                1      0.0       2477        85.0
MYCLOBUTANIL                        1      0.0       2478        85.0
NALED                               3      0.1       2481        85.1
NAPROPAMIDE                         1      0.0       2482        85.2
NICOSULFURON                        2      0.1       2484        85.2
NITROGEN                            1      0.0       2485        85.3
NORFLURAZON                         4      0.1       2489        85.4
ORYZALIN                            3      0.1       2492        85.5
OXADIAZON                           1      0.0       2493        85.6
OXAMYL                              1      0.0       2494        85.6
OXYDEMETON-METHYL                   1      0.0       2495        85.6
OXYFLUORFEN                         1      0.0       2496        85.7
PARAQUAT                            1      0.0       2497        85.7
PARAQUAT DICHLORIDE                 7      0.2       2504        85.9
PCB                                 1      0.0       2505        86.0
PEBULATE                            1      0.0       2506        86.0
PENDIMETHALIN                       6      0.2       2512        86.2
PENTACHLORPHENOL                   17      0.6       2529        86.8
PERMETHRIN                         25      0.9       2554        87.6
PETROLEUM DISTILLATE, OILS, SO      1      0.0       2555        87.7
PHORATE                            29      1.0       2584        88.7
PHOSMET                             4      0.1       2588        88.8
PHOSPHAMIDON                        2      0.1       2590        88.9
PICLORAM                           14      0.5       2604        89.4
POLYCHLORINATED BIPHENYLS           2      0.1       2606        89.4
PROFENOFOS                         18      0.6       2624        90.0
PROMETON                            1      0.0       2625        90.1
PROMETRYN                           3      0.1       2628        90.2
PROPACHLOR                          3      0.1       2631        90.3
PROPANIL                            1      0.0       2632        90.3
PROPICONAZOLE                       1      0.0       2633        90.4
PROPOXUR                            1      0.0       2634        90.4
PYRIDINE                            1      0.0       2635        90.4
RESMETHRIN                          1      0.0       2636        90.5
ROTENONE                            5      0.2       2641        90.6
S-FENVALERATE                       9      0.3       2650        90.9
SETHOXYDIM                          1      0.0       2651        91.0
SIMAZINE                           10      0.3       2661        91.3
SODIUM CYANIDE                     57      2.0       2718        93.3
SODIUM FLUOROACETATE                1      0.0       2719        93.3
STRYCHNINE                          8      0.3       2727        93.6
SULFOMETURON                        1      0.0       2728        93.6
SULFOMETURON METHYL                 8      0.3       2736        93.9
SULPROFOS                           1      0.0       2737        93.9
TEBUTHIURON                         2      0.1       2739        94.0
TEFLUTHRIN                          7      0.2       2746        94.2
```

```
TEMEPHOS                          1      0.0      2747      94.3
TERBUFOS                         55      1.9      2802      96.2
TETRACHLORVINPHOS                 1      0.0      2803      96.2
THALLIUM                          1      0.0      2804      96.2
THIAMETURON-METHYL                2      0.1      2806      96.3

                                               Cumulative   Cumulative
PESTNAME                  Frequency  Percent   Frequency    Percent
_____
THIDIAZURON                       1      0.0      2807      96.3
THIOBENCARB                       1      0.0      2808      96.4
THIOPHANATE-METHYL                1      0.0      2809      96.4
THIRAM                            1      0.0      2810      96.4
TOXAPHENE                        18      0.6      2828      97.0
TRIALLATE                         5      0.2      2833      97.2
TRICHLORFON                       2      0.1      2835      97.3
TRICLOPYR                        12      0.4      2847      97.7
TRIDIPHANE                        1      0.0      2848      97.7
TRIFLURALIN                      54      1.9      2902      99.6
TRIFORINE                         1      0.0      2903      99.6
VERNOLATE                         1      0.0      2904      99.7
WARFARIN                          4      0.1      2908      99.8
ZINC PHOSPHIDE                    6      0.2      2914     100.0
                     Frequency Missing = 61
```

Table G2. Summary of endosulfan incidences by state

STATE	Frequency	Percent	Cumulative Frequency	Cumulative Percent
AL	2	2.3	2	2.3
CA	**29**	**33.3**	**31**	**35.6**
DE	1	1.1	32	36.8
FL	1	1.1	33	37.9
GA	1	1.1	34	39.1
ID	1	1.1	35	40.2
IN	2	2.3	37	42.5
LA	**7**	**8.0**	**44**	**50.6**
MN	2	2.3	46	52.9
MS	1	1.1	47	54.0
NC	**13**	**14.9**	**60**	**69.0**
OR	1	1.1	61	70.1
PA	1	1.1	62	71.3
SC	**16**	**18.4**	**78**	**89.7**
TN	2	2.3	80	92.0
TX	1	1.1	81	93.1
VA	3	3.4	84	96.6
WA	3	3.4	87	100.0

Frequency Missing = 4

Table G3 Summary of incidences associated with endosulfan by groups of organisms affected.

COMMON	Frequency	Percent	Cumulative Frequency	Cumulative Percent
BASS	6	4.4	6	4.4
BEES	2	1.5	8	5.9
BLACK BIRD	1	0.7	9	6.6
BLUE CATFISH	3	2.2	12	8.8
BLUE CRAB	2	1.5	14	10.3
BLUEGILL	3	2.2	17	12.5
BOWFIN	5	3.7	22	16.2
BREAM	1	0.7	23	16.9
BULLHEAD	1	0.7	24	17.6
BULLHEADS	1	0.7	25	18.4
CARP	18	13.2	43	31.6
CATFISH	9	6.6	52	38.2
CHANNEL CATFISH	2	1.5	54	39.7
CLAMS	1	0.7	55	40.4
CRAB	2	1.5	57	41.9
CRAB (STONE)	1	0.7	58	42.6
CRAPPIE	5	3.7	63	46.3
CROAKER	1	0.7	64	47.1
DUCK	2	1.5	66	48.5

COMMON	Frequency	Percent	Cumulative Frequency	Cumulative Percent
EEL	1	0.7	67	49.3
FISH	12	8.8	79	58.1
GAME FISH	1	0.7	80	58.8
GRIZZARD SHAD	1	0.7	81	59.6
LAMPREY	1	0.7	82	60.3
LARGEMOUTH BASS	1	0.7	83	61.0

COMMON	Frequency	Percent	Cumulative Frequency	Cumulative Percent
LETTUCE	2	1.5	85	62.5
MINNOW	2	1.5	87	64.0
MOLLIES	1	0.7	88	64.7
MUD MINNOW	1	0.7	89	65.4

```
MULLET                     9     6.6       98      72.1
N/R                        4     2.9      102      75.0
NO INFORMATION             1     0.7      103      75.7
NON-GAME FISH              1     0.7      104      76.5
NORTHERN PIKE              1     0.7      105      77.2
OYSTER                     1     0.7      106      77.9
PAN FISH                   1     0.7      107      78.7
PICKEREL                   1     0.7      108      79.4
SAFFLOWER                  1     0.7      109      80.1
SHAD                       7     5.1      116      85.3
SHINERS                    1     0.7      117      86.0
SHRIMP                     3     2.2      120      88.2
SILVER MINNOW              1     0.7      121      89.0
SMALL FISH                 1     0.7      122      89.7
SPOT                       2     1.5      124      91.2
STRIPERS                   1     0.7      125      91.9
SUCKER                     1     0.7      126      92.6
SUNFISH                    3     2.2      129      94.9
TILAPIA                    3     2.2      132      97.1
TROUT                      3     2.2      135      99.3
WALLEYE                    1     0.7      136     100.0
              Frequency Missing = 26
```

Table G4. Summary of incidences associated with endosulfan sorted by aquatic or terrestrial species.

TYPEINCI	Frequency	Percent	Cumulative Frequency	Cumulative Percent
AQUATIC	87	95.6	87	95.6
TERRESTRIAL	4	4.4	91	100.0

Table G5. Summary of incidences associated with endosulfan sorted by cause.

CAUSE	Frequency	Percent	Cumulative Frequency	Cumulative Percent
MISUSE(ACCIDENTAL)	28	31.1	28	31.1
MISUSE(INTENTIONAL)	3	3.3	31	34.4
N/R	18	20.0	49	54.4
REGISTERED USE	26	28.9	75	83.3
UNDETERMINED	15	16.7	90	100.0

```
              Frequency Missing = 1
```

Table G6. Summary of incidences assoicated with endosulfan sorted by crop.

TRTSITE	Frequency	Percent	Cumulative Frequency	Cumulative Percent
AGRICULTURAL	23	26.1	23	26.1
ALFALFA	3	3.4	26	29.5
APPLE ORCHAARD	1	1.1	27	30.7
CITRUS	1	1.1	28	31.8
CORN	1	1.1	29	33.0
COTTON	2	2.3	31	35.2
FARMLAND	7	8.0	38	43.2
INDUSTRIAL WASTE	1	1.1	39	44.3
LETTUCE	8	9.1	47	53.4
LETTUCE/CARROTS	1	1.1	48	54.5
ORCHARD	1	1.1	49	55.7
PECAN GROVE	1	1.1	50	56.8
POTATOES	5	5.7	55	62.5
PUMPKIN	1	1.1	56	63.6
RICE	1	1.1	57	64.8
SOYBEANS	1	1.1	58	65.9
TOBACCO	9	10.2	67	76.1
TOMATO/CUCUMBER	1	1.1	68	77.3
TOMATOES	7	8.0	75	85.2
UNKNOWN	13	14.8	88	100.0

Frequency Missing = 3

Table G7. Summary of incidents associated with endosulfan sorted by weather conditions.

WEATHERC	Frequency	Percent	Cumulative Frequency	Cumulative Percent
9 INCHES RAIN	1	1.1	1	1.1
2 1/2 INCHES RAIN	1	1.1	2	2.2
2-1/2 INCHES RAIN	1	1.1	3	3.3
4 INCHES RAIN	1	1.1	4	4.4
CLEAR	3	3.3	7	7.8
FOGGY	1	1.1	8	8.9
HEAVY RAIN	1	1.1	9	10.0
N/R	56	62.2	65	72.2
NO RAIN	1	1.1	66	73.3
RAIN	23	25.6	89	98.9
RAIN FOLLOWED APPLTN	1	1.1	90	100.0

Frequency Missing = 1

Table G8. Average number of species affected in endosulfan-related incidents.

Analysis Variable : Total number of organisms affected.

```
-------------------------------- CLASSORGAN= --------------------------------
                 Mean      Std Error        Range
               -----------------------------------------
                5.0000000    5.0000000   20.0000000
               -----------------------------------------


------------------------------- CLASSORGAN=BIRD -------------------------------
                 Mean      Std Error        Range
               -----------------------------------------
                26676.67    13323.33     39970.00
               -----------------------------------------
```

144

```
----------------------------- CLASSORGAN=CROAKER ----------------------------
                 Mean      Std Error        Range
              -----------------------------------------
               1800.00           .             0
              -----------------------------------------


---------------------------- CLASSORGAN=CRUSTACEAN --------------------------
                 Mean      Std Error        Range
              -----------------------------------------
               644.4444444   324.5129304    2200.00
              -----------------------------------------


------------------------------- CLASSORGAN=FISH -----------------------------
                 Mean      Std Error        Range
              -----------------------------------------
               5089.96       2449.27      240000.00
              -----------------------------------------


------------------------------ CLASSORGAN=INSECT ----------------------------
                 Mean      Std Error        Range
              -----------------------------------------
                  0             0             0
              -----------------------------------------


----------------------------- CLASSORGAN=MOLLUSK ----------------------------
                 Mean      Std Error        Range
              -----------------------------------------
               2200.00           .             0
              -----------------------------------------


------------------------------ CLASSORGAN=PLANT -----------------------------
                 Mean      Std Error        Range
              -----------------------------------------
               833.3333333   600.9252126    2000.00
              -----------------------------------------
```

Table G9. Summary of endosulfan-related incidents sorted by state and year.

```
---------------------------------- STATE= -----------------------------------
                                Cumulative   Cumulative
            Y   Frequency   Percent  Frequency     Percent

          _____
          1992       1       25.0        1          25.0
          1993       1       25.0        2          50.0
          1994       1       25.0        3          75.0
          1995       1       25.0        4         100.0


--------------------------------- STATE=AL ----------------------------------
                                Cumulative   Cumulative
            Y   Frequency   Percent  Frequency     Percent

          _____
          1995       2      100.0        2         100.0
```

145

```
---------------------------------- STATE=CA ----------------------------------
                                  Cumulative  Cumulative
          Y    Frequency   Percent  Frequency    Percent
        _____
        1971          1     3.4          1        3.4
        1973          1     3.4          2        6.9
        1974          1     3.4          3       10.3
        1975          2     6.9          5       17.2
        1976          8    27.6         13       44.8
        1977          2     6.9         15       51.7
        1978          5    17.2         20       69.0
        1988          4    13.8         24       82.8
        1989          1     3.4         25       86.2
        1996          4    13.8         29      100.0


---------------------------------- STATE=DE ----------------------------------
                                  Cumulative  Cumulative
          Y    Frequency   Percent  Frequency    Percent
        _____
        1992          1   100.0          1      100.0


---------------------------------- STATE=FL ----------------------------------
                                  Cumulative  Cumulative
          Y    Frequency   Percent  Frequency    Percent
        _____
        1994          1   100.0          1      100.0


---------------------------------- STATE=GA ----------------------------------
                                  Cumulative  Cumulative
          Y    Frequency   Percent  Frequency    Percent
        _____
        1992          1   100.0          1      100.0


---------------------------------- STATE=ID ----------------------------------
                                  Cumulative  Cumulative
          Y    Frequency   Percent  Frequency    Percent
        _____
        1974          1   100.0          1      100.0


---------------------------------- STATE=IN ----------------------------------
                                  Cumulative  Cumulative
          Y    Frequency   Percent  Frequency    Percent
        _____
        1992          2   100.0          2      100.0


---------------------------------- STATE=LA ----------------------------------
                                  Cumulative  Cumulative
          Y    Frequency   Percent  Frequency    Percent
        _____
        1991          1    16.7          1       16.7
        1994          1    16.7          2       33.3
        1996          4    66.7          6      100.0
                    Frequency Missing = 1
```

```
------------------------------- STATE=MN -------------------------------
                                     Cumulative  Cumulative
         Y   Frequency   Percent     Frequency     Percent
        _____
        1971         2     100.0             2       100.0


------------------------------- STATE=MS -------------------------------
                                     Cumulative  Cumulative
         Y   Frequency   Percent     Frequency     Percent
        _____
        1989         1     100.0             1       100.0


------------------------------- STATE=NC -------------------------------
                                     Cumulative  Cumulative
         Y   Frequency   Percent     Frequency     Percent
        _____
        1970         2      15.4             2        15.4
        1971         1       7.7             3        23.1
        1973         1       7.7             4        30.8
        1990         1       7.7             5        38.5
        1991         2      15.4             7        53.8
        1992         4      30.8            11        84.6
        1994         2      15.4            13       100.0


------------------------------- STATE=OR -------------------------------
                                     Cumulative  Cumulative
         Y   Frequency   Percent     Frequency     Percent
        _____
        1973         1     100.0             1       100.0


------------------------------- STATE=PA -------------------------------
                                     Cumulative  Cumulative
         Y   Frequency   Percent     Frequency     Percent
        _____
        1971         1     100.0             1       100.0


------------------------------- STATE=SC -------------------------------
                                     Cumulative  Cumulative
         Y   Frequency   Percent     Frequency     Percent
        _____
        1979         4      25.0             4        25.0
        1980         5      31.3             9        56.3
        1981         1       6.3            10        62.5
        1982         3      18.8            13        81.3
        1983         1       6.3            14        87.5
        1985         1       6.3            15        93.8
        1992         1       6.3            16       100.0


------------------------------- STATE=TN -------------------------------
                                     Cumulative  Cumulative
         Y   Frequency   Percent     Frequency     Percent
        _____
        1992         2     100.0             2       100.0
```

```
--------------------------------- STATE=TX ----------------------------------
                                      Cumulative  Cumulative
           Y    Frequency   Percent   Frequency    Percent
          _____
          1997          1     100.0           1      100.0


--------------------------------- STATE=VA ----------------------------------
                                      Cumulative  Cumulative
           Y    Frequency   Percent   Frequency    Percent
          _____
          1994          2      66.7           2       66.7
          1996          1      33.3           3      100.0


--------------------------------- STATE=WA ----------------------------------
                                      Cumulative  Cumulative
           Y    Frequency   Percent   Frequency    Percent
          _____
          1970          1      33.3           1       33.3
          1972          2      66.7           3      100.0


--------------------------------- STATE=AL ----------------------------------
       Y                                       Frequency Count
                                                         Sum
          é
  1995    é****************************************      2.000000
          é
          è___ê___ê___ê___ê___ê___ê___ê___ê___ê___ê
            0.2 0.4 0.6 0.8  1  1.2 1.4 1.6 1.8  2
                      Frequency Count
```

148

```
---------------------------------- STATE=CA ----------------------------------
         Y                                          Frequency Count
                                                               Sum
            é
    1971    é*****                                        1.000000
            é
    1973    é*****                                        1.000000
            é
    1974    é*****                                        1.000000
            é
    1975    é**********                                   2.000000
            é
    1976    é****************************************     8.000000
            é
    1977    é**********                                   2.000000
            é
    1978    é************************                     5.000000
            é
    1988    é*******************                          4.000000
            é
    1989    é*****                                        1.000000
            é
    1996    é*******************                          4.000000
            é
            è____ê____ê____ê____ê____ê____ê____ê____ê
                 1    2    3    4    5    6    7    8
                          Frequency Count


---------------------------------- STATE=DE ----------------------------------
       Y                                            Frequency Count
                                                               Sum
          é
  1992    é*********************************************    1.000000
          é
          è____ê____ê____ê____ê____ê____ê____ê____ê____ê____ê
               0.1  0.2  0.3  0.4  0.5  0.6  0.7  0.8  0.9   1
                          Frequency Count


---------------------------------- STATE=FL ----------------------------------
       Y                                            Frequency Count
                                                               Sum
          é
  1994    é************************************************    1.000000
          é
          è____ê____ê____ê____ê____ê____ê____ê____ê____ê____ê
               0.1  0.2  0.3  0.4  0.5  0.6  0.7  0.8  0.9   1
                          Frequency Count


---------------------------------- STATE=GA ----------------------------------
       Y                                            Frequency Count
                                                               Sum
          é
  1992    é*************************************************    1.000000
          é
          è____ê____ê____ê____ê____ê____ê____ê____ê____ê____ê
               0.1  0.2  0.3  0.4  0.5  0.6  0.7  0.8  0.9   1
                          Frequency Count
```

149

```
-------------------------------- STATE=ID -----------------------------------
      Y                                           Frequency Count
                                                               Sum
        é
  1974  é**********************************************      1.000000
        é
        è____ê____ê____ê____ê____ê____ê____ê____ê____ê____ê
             0.1  0.2  0.3  0.4  0.5  0.6  0.7  0.8  0.9   1
                        Frequency Count


-------------------------------- STATE=IN -----------------------------------
      Y                                           Frequency Count
                                                               Sum
        é
  1992  é*************************************       2.000000
        é
        è___ê___ê___ê___ê___ê___ê___ê___ê___ê___ê
           0.2 0.4 0.6 0.8  1  1.2 1.4 1.6 1.8  2
                        Frequency Count


-------------------------------- STATE=LA -----------------------------------
      Y                                           Frequency Count
                                                               Sum
        é
  1991  é**********                                  1.000000
        é
  1994  é**********                                  1.000000
        é
  1996  é****************************************    4.000000
        é
        è_____ê_____ê_____ê_____ê
                  1         2         3         4
                        Frequency Count


-------------------------------- STATE=MN -----------------------------------
      Y                                           Frequency Count
                                                               Sum
        é
  1971  é************************************       2.000000
        é
        è___ê___ê___ê___ê___ê___ê___ê___ê___ê___ê
           0.2 0.4 0.6 0.8  1  1.2 1.4 1.6 1.8  2
                        Frequency Count


-------------------------------- STATE=MS -----------------------------------
      Y                                           Frequency Count
                                                               Sum
        é
  1989  é***********************************************      1.000000
        é
        è____ê____ê____ê____ê____ê____ê____ê____ê____ê____ê
             0.1  0.2  0.3  0.4  0.5  0.6  0.7  0.8  0.9   1


                        Frequency Count
```

```
--------------------------------- STATE=NC ----------------------------------
         Y                                              Frequency Count
                                                                    Sum
            é
    1970    é*******************                          2.000000
            é
    1971    é**********                                   1.000000
            é
    1973    é**********                                   1.000000
            é
    1990    é**********                                   1.000000
            é
    1991    é********************                         2.000000
            é
    1992    é****************************************     4.000000
            é
    1994    é*******************                          2.000000
            é
            è_____ê_____ê_____ê_____ê
                      1         2         3         4
                            Frequency Count


--------------------------------- STATE=OR ----------------------------------
         Y                                              Frequency Count
                                                                    Sum
          é
    1973  é*************************************************  1.000000
          é
          è____ê____ê____ê____ê____ê____ê____ê____ê____ê____ê
              0.1  0.2  0.3  0.4  0.5  0.6  0.7  0.8  0.9   1
                            Frequency Count


--------------------------------- STATE=PA ----------------------------------
         Y                                              Frequency Count
                                                                    Sum
          é
    1971  é*************************************************  1.000000
          é
          è____ê____ê____ê____ê____ê____ê____ê____ê____ê____ê
              0.1  0.2  0.3  0.4  0.5  0.6  0.7  0.8  0.9   1
                            Frequency Count


--------------------------------- STATE=SC ----------------------------------
         Y                                              Frequency Count
                                                                    Sum
           é
    1979   é*************************************          4.000000
           é
    1980   é************************************************  5.000000
           é
    1981   é**********                                    1.000000
           é
    1982   é***************************                   3.000000
           é
    1983   é**********                                    1.000000
           é
    1985   é**********                                    1.000000
           é
    1992   é**********                                    1.000000
           é
           è_____ê_____ê_____ê_____ê_____ê
                     1         2         3         4         5
                            Frequency Count


                                    151
```

```
--------------------------------- STATE=TN ---------------------------------
        Y                                        Frequency Count
                                                             Sum
             é
     1992    é**************************************           2.000000
             é
             è___ê___ê___ê___ê___ê___ê___ê___ê___ê___ê
                0.2 0.4 0.6 0.8  1  1.2 1.4 1.6 1.8  2
                        Frequency Count


--------------------------------- STATE=TX ---------------------------------
      Y                                          Frequency Count
                                                             Sum
           é
   1997    é***************************************************   1.000000
           é
           è____ê___ê___ê___ê___ê___ê___ê___ê___ê___ê
              0.1  0.2  0.3  0.4  0.5  0.6  0.7  0.8  0.9   1
                        Frequency Count

--------------------------------- STATE=VA ---------------------------------
        Y                                        Frequency Count
                                                             Sum
             é
     1994    é****************************************       2.000000
             é
     1996    é*******************                            1.000000
             é
             è___ê___ê___ê___ê___ê___ê___ê___ê___ê___ê
                0.2 0.4 0.6 0.8  1  1.2 1.4 1.6 1.8  2
                        Frequency Count


--------------------------------- STATE=WA ---------------------------------
        Y                                        Frequency Count
                                                             Sum
             é
     1970    é*******************                            1.000000
             é
     1972    é************************************           2.000000
             é
             è___ê___ê___ê___ê___ê___ê___ê___ê___ê___ê
                0.2 0.4 0.6 0.8  1  1.2 1.4 1.6 1.8  2
                        Frequency Count
```

152

Table G10. Summary of incidents[1] in California by cause and certainty index.

OBS	Type Incident	Cause	Certainity Index	Year
1	AQUATIC	MISUSE(ACCIDENTAL)	HIGHLY PROBABLE	1971
2	AQUATIC	MISUSE(ACCIDENTAL)	PROBABLE	1973
3	AQUATIC	MISUSE(ACCIDENTAL)	PROBABLE	1974
4	AQUATIC	MISUSE(ACCIDENTAL)	PROBABLE	1975
5	AQUATIC	REGISTERED USE	POSSIBLE	1975
6	AQUATIC	MISUSE(INTENTIONAL)	PROBABLE	1976
7	AQUATIC	REGISTERED USE	HIGHLY PROBABLE	1976
8	AQUATIC	REGISTERED USE	HIGHLY PROBABLE	1976
9	AQUATIC	REGISTERED USE	POSSIBLE	1976
10	AQUATIC	REGISTERED USE	HIGHLY PROBABLE	1976
11	AQUATIC	MISUSE(ACCIDENTAL)	HIGHLY PROBABLE	1976
12	AQUATIC	MISUSE(ACCIDENTAL)	PROBABLE	1976
13	AQUATIC	MISUSE(ACCIDENTAL)	PROBABLE	1976
14	AQUATIC	MISUSE(ACCIDENTAL)	HIGHLY PROBABLE	1977
15	AQUATIC	REGISTERED USE	HIGHLY PROBABLE	1977
16	AQUATIC	N/R	HIGHLY PROBABLE	1978
17	AQUATIC	UNDETERMINED	POSSIBLE	1978
18	AQUATIC	UNDETERMINED	PROBABLE	1978
19	AQUATIC	UNDETERMINED	HIGHLY PROBABLE	1978
20	AQUATIC	UNDETERMINED	UNLIKELY	1978
21	AQUATIC	MISUSE(ACCIDENTAL)	POSSIBLE	1988
22	AQUATIC	N/R	HIGHLY PROBABLE	1988
23	AQUATIC	N/R	HIGHLY PROBABLE	1988
24	AQUATIC	N/R	PROBABLE	1988
25	AQUATIC	REGISTERED USE	POSSIBLE	1989
26	AQUATIC	MISUSE(INTENTIONAL)	HIGHLY PROBABLE	1996
27	AQUATIC	REGISTERED USE	PROBABLE	1996
28	AQUATIC	N/R	PROBABLE	1996
29	AQUATIC	N/R	HIGHLY PROBABLE	1996

[1]although 29 incidents are reported, two recent incidents for 1996 have recently been reported for California bringing the total number of incidents in 1996 to six.

Introduction

To further explore the likelihood of exceedances of aqautic LOCs, a distribution analysis of risk quotients was conducted using Monte Carlo simulations (Crystal Ball). Aquatic EEC and LC_{50} distribution using acute toxicity estimates for fish were generated and then used to stochastically predict RQ distributions. The simulation model was based on the following formula:

$$\text{RQ distribution} = \frac{\text{EEC distribution}}{LC_{50} \text{ distribution}}$$

The resulting RQ distribution for freshwater fish was used to predict mean and upper 10th percentile RQs, RQ range, and the probability of exceeding the acute high risk level of concern (RQ ˘ 0.5). The EEC distribution consisted of multi-year annual peak runoff concentrations (20 to 36 years data) predicted by PRZM/EXAMS simulations based on established input scenarios for cotton, tomatos, grapes, tobacco, pecans, lettuce, potatoes, and apples and was also based on a single isomer of endosulfan (˝ endosulfan) alone. The toxicity distribution was fitted using LC_{50} values from twelve freshwater acute toxicity studies involving four species of fish (bluegill sunfish, rainbow trout, catfish and fathead minnow).

Procedures

The following procedures and guidelines were followed for the simulation:

1) Determination of the simulation objective and models

In this study, the objective of the simulation was to develop a freshwater fish RQ distribution. The formula of " RQ-distribution = EEC-distribution / LC50-distribution" was used as the model to stochastically predict the RQ-distribution.

2) Distribution fitting of assumption (input) data (EECs and LC_{50} s); and goodness of fit

The exposure distribution was determined with multi-crop (cotton, tomatos, grapes, tobacco, pecans, lettuce, potatoes, and apples) EEC data from PRZM/EXAM runs using Crystal Ball's distribution fitting utility. The same procedure was used to select a representative LC_{50} distribution based on acute toxicity estimates for freshwater fish. Lognormal distributions were assumed to be most representative of both the EEC and LC_{50} data. Chi-Square was used to verify the goodness of fit.

3) Monte Carlo simulation using Crystal Ball

After the simulation was completed and the RQ distribution produced, the acute high risk LOC value (RQ ˘ 0.5) served as a basis for estimating the probability (or % certainty) of obtaining an RQ value greater than or equal to the LOC.

4) Inference of simulation results

Based on the distribution of RQ values, an average RQ, a range of RQ values, and information on the probability of exceeding the acute high risk LOC for freshwater fish were obtained.

Results

Based on the distribution analysis of acute freshwater fish RQ values, the average RQ value is 3.45 (range 0.84 - 7.4). Except for apples, the probability that the RQ value will exceed the acute high risk LOC is greater than 99%. For apples, the probability of exceedance was greater than 50%. It is noteworthy that the distribution analysis was based on estimated environmental concentrations for ˝ -endosulfan and that EECs would likely be higher had the ˘ -endosulfan isomer and the endosulfan sulfate degradate been included. Additionally, the LC_{50} distribution was based on acute freshwater fish toxicity estimates; acute toxicity estimates for estuarine/marine fish were roughly an order of magnitude more sensitive. Thus, while Monte Carlo simulations for freshwater fish RQ values are not conservative, on 7 out of the 8 (88%) of the crops modeled, the probability of exceeding high acute risk LOCs for freshwater fish is greater than 99%.

Table I-1. Organisms used to define aquatic universe

Genus/Species	LC_{50} [ppb]	Rank	Percentile
Morone saxatillis	0.1	1	0.091
Lagodon rhomboides	0.3	2	0.182
Oncorhynchus mykiss	1.01 (geomean of 0.80, 1.5,1.1,0.37)	3	0.273
Pylodictus olivarius	1.13 (geomean of 1.5, 0.86)	4	0.364
Ictalurus nebulosus	1.5	5	0.454
Pimephales promelas	1.5	6	0.545
Lepomis macrochirus	1.93 (geomean of1.7, 2.08, 3.3, 1.2)	7	0.636
Callinectes sapidus	19	8	0.727
Crassostrea virginca	42	9	0.818
Uca sp.	790	10	0.909

Probabilistic Exposure Assessment of an Aquatic System

This analysis depicts one way of quantifying the probability and extent of detrimental effects on an aquatic system that may be caused by using endosulfan under typical use conditions. As further explained below, we use the LC_{50}s of 10 relatively insensitive species to approximate the range of LC_{50}s for all aquatic species in an attempt to roughly and nonconservatively model an overall aquatic ecosystem. Although admittedly crude, this analysis does provide a first step into probabilistic modeling of overall aquatic effects and provides useful insight towards better understanding of the range of endosulfan's ecological effects.

Characterization of Acute Exposure

Exposure distributions were calculated with PRZM/EXAMS using the eight crop scenarios previously described (see Table 3 in the Water Resource Assessment). Typical application rates as supplied by BEAD (see Table 3 in main document) were used for the simulation. In order to take into account the required 300-ft buffer, spray drift input was excluded. Thus, these simulations should not be viewed as conservative. For each scenario, the highest 96-hour-averaged concentration (acute exposure) was determined for each year of the simulation period (simulation periods ranged from 20 to 36 years, depending on the availability weather data).

The 96-hour average concentrations were selected in order to correspond with the exposure period of the toxicity data (described below). Using the 96-hour exposure concentrations is a nonconservative assumption, since actual peak concentrations will be much higher than 96-hour averaged concentrations, and thus we ignore the potential latent toxicological effects that might result from the actual higher peak concentrations. Also, the probability of a concentration exceedance was based on single annual 96-hour maximums, since only a single event per year is necessary to cause detrimental effects. Others (e.g., Soloman et al. 1996) have proposed basing the exposure probability on the fraction of time that a critical concentration is exceeded during a year or a season, but such approaches downplay the detrimental effects of acute exposure from single events during a year. In other words, the present assessment is intended to give the probability of an event occurring during any year, rather than the probability of an event occurring during any given day.

The 96-hour concentrations were then fit by least squares to a log-normal cumulative distribution after ranking the individual concentrations by n/(N+1), where N is the total number of data points and n is the rank of the concentration in ascending order. The fittings, performed solely mathematical convenience (i.e., for interpolation of data), adequately simulated the concentration data (see Figure I-1). A summary of the fitted parameters is given in Table I-1

Characterization of Effects

Table I-2 lists the species and their LC_{50}s that are intended here to represent the ecosystem modeled. In an attempt be nonconservative, we did not select the most sensitive species to represent the ecosystem. Clearly, it is not possible to test all species in an aquatic system, but the organisms given in Table I-2 provide the best available distribution of organisms for the purpose of this nonconservative

probabilistic assessment.

From these species, a cumulative distribution curve was created in a manner similar to that of Klaine et al.(1996) by ranking the data by n/(N+1) where N is the total number of data points and n is the rank of the LC_{50} in ascending order. For mathematical convenience (i.e., data interpolation), these data were fit to a cumulative log-normal distribution. Fitted parameters are given in the last row of Table I-1.

Table I-1. Fitted parameters used to simulate data

Description of Fitted Data	Mean of ln-transformed Data	Std. Dev. of ln-transformed Data
apple scenario	-2.47	0.537
potato scenario	-1.02	0.605
lettuce scenario	-0.800	0.679
tobacco scenario	-0.540	0.678
cotton scenario	-0.376	0.675
pecan scenario	1.151	0.567
tomato scenario	1.46	0.493
LC50 data	0.326	1.64

Table I-2. Organisms used to define aquatic universe

Genus/Species	LC_{50} [ppb]	Rank	Percentile
Morone saxatillis	0.1	1	0.091
Lagodon rhomboides	0.3	2	0.182
Oncorhynchus mykiss	1.01 (geomean of 1.7, 1.5,1.1,0.37)	3	0.273
Pylodictus olivarius	1.13 (geomean of 1.5, 0.86)	4	0.364
grass shrimp	1.3	5	0.454
Ictalurus nebulosus	1.5	6	0.545
Pimephales promelas	1.5	7	0.636
Lepomis macrochirus	1.93 (geomean of1.7, 2.08, 3.3, 1.2)	8	0.727
Callinedes sapidas	19	9	0.818
Fiddler Crab	790	10	0.909

Analysis of Distributions

157

The apple scenario is used as an example of calculations for the probability and extent of detrimental effects on an aquatic environment. Figure I-1 shows the cumulative distribution of maximum annual 96-hour averaged concentrations. Also shown in Figure 1 is the fraction of species affected at any given aquatic concentration. The log-normal fits to both curves are also shown. This example (see dotted lines) shows that there is a 10% chance (90% cumulative) that EECs will exceed 0.17 ppb. At the EEC level of 0.17 ppb, at least 10% of aquatic species will be adversely affected (i.e., the LC50 will be exceeded).

This graph can be presented in a more easy-to-read form by transforming the x-axis of the species distribution to equivalent units of EEC probability. The x-axis change is accomplished by the following process:

The normal cumulative distribution for the log-transformed EEC data is simulated by

$$y_1 = \frac{erf\left(\dfrac{x - \mu_{EEC}}{\sqrt{2}\sigma_{EEC}}\right) + 1}{2} \tag{1}$$

where y1 is the probability that a log-transformed EEC will be less than x. Therefore, the probability that a log-transformed EEC exceeds x is

$$X = 1 - y_1 = \frac{1 - erf\left(\dfrac{x - \mu_{EEC}}{\sqrt{2}\sigma_{EEC}}\right)}{2} \tag{2}$$

where X is the probability that an EEC will be exceeded and will be the abscissa of the transformed graph (presented later). Solving equation (2) for x yields

$$x = \sqrt{2}\sigma_{EEC}erfinv(1 - 2X) + \mu_{EEC} \tag{3}$$

Turning our attention to the ecological effects data, the normal cumulative distribution for the log-transformed LC_{50} data is simulated by

$$Y = \frac{erf\left(\dfrac{x - \mu_{LC50}}{\sqrt{2}\sigma_{LC50}}\right) + 1}{2} \tag{4}$$

where Y represents the fraction of species that will be detrimentally affected by a log-transformed EEC of x. Substituting equation (3) into equation (4) gives the appropriate transformation for evaluating the probability and extent of detrimental effects on an aquatic ecosystem:

$$Y = \frac{erf\left(\dfrac{\sqrt{2}\sigma_{EEC}erfinv(1-2X)+\mu_{EEC}-\mu_{LC50}}{\sqrt{2}\sigma_{LC50}}\right)+1}{2}$$

(5)

Alternatively, this transformation can be readily performed by using the following Microsoft Excel function:

Y = NORMDIST(NORMINV(X, μ_{EEC}, σ_{EEC}, TRUE), μ_{LC50}, σ_{LC50}, TRUE)

where   Y = the fraction of species affected,
      X = the probability of attaining or exceeding an EEC,
      μ_{EEC} = the mean of the log-transformed EEC data,
      σ_{EEC} = the standard deviation of the log-transformed EEC data,
      μ_{LC50} = the mean of the log-transformed LC_{50} data,
      σ_{LC50} = the standard deviation of the log-transformed LC_{50} data,
      erf is the error function, and
      erfinv is the inverse error function.

The transformed graphs for all eight crop scenarios are given in Figure I-2

Discussion of Results

Figure I-2 shows the relationship of the fraction of species affected by the likelihood of exceeding an EEC for all eight crop scenarios. The x axis shows the probability of exceeding an EEC during any given year, and the y axis shows the fraction of species (in this modeled aquatic system) that will be adversely affected by the EEC. Clearly, there is a wide range of effects that are likely to occur. For example, there is a 50% probability that at least 5% of species will be detrimentally affected with an apple scenario, but there is a 50% probability that at least 75% of species will be detrimentally affected for the Florida tomato scenario. At the 10% level of EEC occurrence (EFED's normal evaluation level), the fraction of species detrimentally affected range from 10% to 75%. Even with the nonconservative methods used in this analysis, it is apparent from the above graph that there is a very strong likelihood that detrimental ecological effects will occur during any given year.

Figure I-1. Cumulative distribution plots of LC_{50} data and 96-hr averaged EECs for New York apple scenario. Also shown are the best fits of log-normal distributions. Dotted lines show the method of axis transformation (see text).

Figure I-2. Extent of detrimental effects as a function of the likelihood of attaining an EEC. The x-axis represents the probability of attaining an EEC during any year, and the y-axis represents the fraction of species that will be detrimentally affected at that EEC.

References

Klaine, S.J., Cobb, G.P., Dickerson, R.L., Dixon, K.R., Kendall. R.J., Smith, E.E., and Solomon, K.R., (1996). An Ecological Risk Assessment for the Use of the Biocide, Dibromonitrilopropionide (DBNPA), in Industrial Cooling Systems, *Environmental Toxicology and Chemistry*. 15(1), 21-30.

Solomon, K.R. Baker, D.B., Richards, R.P., Dixon, K.R, Klaine, S.J., La Point, T.W., Kendall. Weisskopf, C.P., Giddings, J.M., Giesy, J.P., Hall, L.W. Williams, J.P.(1996). Ecological Risk Assessment of Atrazine in North American Surface Waters, *Environmental Toxicology and Chemistry*. 15(1), 31-76.

Technical grade endosulfan and each of the ˝ - and ˘ -isomers were estrogenic at concentrations of 10 to 25 . M as measured in the E-screen test using Michigan Cancer Foundation human breast cancer estrogen sensitive cells (MCF-7 cells) (Soto *et al.* 1995). At concentrations of 2.5 x 10^{-5} M endosulfan resulted in a 4-fold induction in a yeast-based estrogenic response assay (Ramamoorthy *et al.* 1997) More recent *in vitro* studies (Massaad and Barouki 1999) have detected significant estrogenic activity of endosulfan at concentrations as low as 10^{-6} M. Although endosulfan's affinity for the human estrogen receptor is reported to be considerably lower than the endogenous estradiol (Heufelder and Hofbauer 1996), its ability to bind to the receptor at all renders the chemical capable of competing with the endogenous hormone and capable of eliciting hormone-like effects. Exogenous agents that interfere with the production, release, transport, metabolism, binding, action or elimination of endogenous hormones responsible for homeostasis and the regulation of developmental processes in organisms have been referred to as endocrine disruptors (Ankley *et al.* 1998). Any exogenous agent that causes adverse effects in an intact organism or its progeny, consequent to changes in endocrine function, qualifies as an endocrine disruptor (Gillesby and Zacharewski 1998). Based on this definition and the ability of endosulfan to bind to the estrogen receptor, endosulfan is classified as an endocrine disruptor. Whether the toxicity endpoints observed during chronic toxicity studies of endosulfan are a result of endocrine disruption in nontarget organisms is not known. However, it is clear that organisms treated with endosulfan did exhibit some toxic effects that have historically been associated with endocrine disrupting chemicals, *e.g.*, developmental effects (Ankley *et al.* 1998).

Exposure to endosulfan has resulted in both reproductive and developmental effects in nontarget animals. Tadpoles exposed to endosulfan for 96 hours followed by a 10-day recovery period exhibited significantly higher post-exposure mortality (Berrill *et al.* 1998). Mean length of unexposed tadpoles was significantly larger ($P < 0.01$) than the mean length of tadpoles exposed to 0.132 mg/L endosulfan. Relative to controls, endosulfan-treated tadpoles had impaired development and failed to metamorphose. The study concluded that at concentrations likely to be encountered in the environment, 2-week-old tadpoles exhibited greater sensitivity of posthatching development of the neuromuscular system. Additionally, studies on the intersexuality of the genital system in birds revealed that endosulfan impaired the development of the avian genital tract (Lutz and Lutz-Ostertag 1975). In mammalian studies, endosulfan increased the rate of testosterone biotransformation and clearance (Wilson and LeBlanc 1997) and has exhibited proliferative, estrogen-like effects in MCF7 cells at doses of 4 ppm (Soto *et al.*, 1994). Endosulfan produced testicular atrophy in male rats fed a diet containing 10 ppm (NCI 1978; Gupta and Gupta 1979) and lowered gonadotropin and testosterone plasma levels. Recent studies (Dalsenter et al. 1999) have also demonstrated that daily sperm production was permanently decreased in rat offspring treated with 3 ppm endosulfan *in utero* and during lactation.

EPA is required under Federal Food, Drug, and Cosmetic Act (FFDCA), as amended by the Food Quality Protection Act, to develop a screening program to determine whether certain substances (including all pesticide active and other ingredients) "may have an effect in humans that is similar to an effect produced by a naturally-occurring estrogen, or other such endocrine effects as the Administrator may designate." Following the recommendations of its Endocrine Disrupting Screening and Testing Advisory Committee (EDSTAC), EPA determined that there was scientific basis for including, as part of the program, the androgen- and thyroid-hormone systems, in addition to the estrogen-hormone system. EPA also adopted EDSTAC's recommendation that the Agency include evaluations of potential effects

in wildlife. For pesticidal chemicals, EPA will use FIFRA and, to the extent that effects in wildlife may help determine whether a substance may have an effect in humans, FFDCA authority to require the wildlife evaluations. As the science develops and resources allow, screening of additional hormone systems may be added to the Endocrine Disruptor Screening Program (EDSP)

Endosulfan has demonstrated both reproductive and developmental effects in a broad range of organisms and has been implicated in peer-reviewed literature as an endocrine disrupting agent. Based on the chronic effects of endosulfan and open literature, EFED recommends that when appropriate screening and/or testing protocols being considered under the Agency's EDSP have been developed, endosulfan be subjected to more definitive testing to better characterize effects related to its endocrine disruptor activity.